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SCANDINAVIAN EXPERIMENTS WITH SUBMARINE MINES.

TRANSLATED FROM THE ORIGINAL DANISH BY LIEUT. W. H. BEEHLER, U. S. N.

This paper contains some of the most prominent features of the Scandinavian experiments with submarine mines. I have obtained this information from my translation of the official reports entitled: "*Rapport over Forsæg med Sæminer, foretagne af Sverige, Norge og Danmark i forening 1874–76*" with "*Bilag No. 1*"—"*Journal over forsæg med Sæminer*" and "*Bilag No. 2*"—"*Beretning om nogle fosog med Sæminer udforte in Carlksrona in October 1873.*

These experiments were conducted by a board of three officers representing Sweden, Norway and Denmark, at Carlskrona, Sweden, though one class of experiments was made at Copenhagen. This board made a thorough scientific investigation into submarine mines, exchanged their results with other European governments, and based their general conclusions upon all the facts known up to the date of their final report, made July 1st, 1877. I believe that these results, with their conclusions therefrom, form the most reliable and thorough treatise on the action, effect, and general application of submarine mines yet published. They divided the subject into four classes; A, Igniting experiments; B, Experiments with a double bottom ship

equal in all respects to the English iron-clad "Hercules"; C, Experiments with Armor; and D, Countermine Experiments.

Before undertaking these experiments the board made a scientific investigation of the nature of a submerged explosion, and deduced certain laws to express the relation between the depth, charge and distance, and the effects. They divide the effects into two divisions; direct and indirect, and thus determine the effective use of all kinds of submarine mines. They base their investigation upon the known laws governing the explosion of mines in earth, and then, by comparing the two media, deduce theoretical laws which they finally prove by actual experiment. I shall give a concise statement of their methods and the results deduced, and then show how far these results have been demonstrated by their experiments. Unless stated otherwise, the dimensions, weights, &c., are given in English feet and inches, English pounds, &c.

"When a mine explodes in the earth, it raises cohesive masses of earth, compressing some parts and detaching others. If the mine is not too deep it will raise a sundered mass of earth and leave a crater; the earth will tremble beyond the crater for a short time and leave the limits of the direct and indirect effects distinctly marked.

In water, however, the gases evolved press the particles apart instantaneously, and the cavity is filled again almost immediately, so that it is rather difficult to measure the extent of the crater and thus determine the limit of the direct effect. The vibrating area is much greater in water than in earth, and certain definite effects are obtained which are very valuable in the use of countermines."

They assume that it will be impossible to breach a ship unless she is within the limit of the direct effects, and they make their calculations as to the extent of this from explosions of ordinary gunpowder.

"Since an explosion of a charge of gunpowder (submerged so as to be remote from the bottom) forces the surrounding masses of water aside, we will suppose the resistance to be equal in all directions, and then compare the action of the disengaged gases with that of a sphere of gas surrounded by concentric layers of water.

The volume of this sphere, or the cube of its radius, can be regarded as proportional to the charge, so that if L=the charge, R=the radius of the sphere, and M=a coëfficient to be determined, we may express this action by $L=M R^3$. . . . . (1).

This sphere will evidently indicate the limits of the direct effects, and we will designate its radius as the radius of explosion, or R,

which will thus serve as the measure of the force of the explosion. It is evident that the value of R will depend upon the depth and the pressure exerted.

In water the explosion remains concealed below the surface for an instant only; the sphere of gas then begins to ascend with great velocity and carries a mass of water before it, which is thrown out to various heights. If the charge is very deep, the sphere of gas will decrease as it rises, lose its tension, and finally become absorbed so that there will be only a slight ebullition on the surface. In this case the mine is said to be completely smothered. If this same charge is brought nearer the surface, it will soon have a depth at which it will cease to be smothered and, in this investigation, this depth is designated the least depth for smothered mines.

If this charge is brought still nearer the surface, the explosion will cause a funnel-shaped opening or crater in the water. F K M N G (Fig. 1).

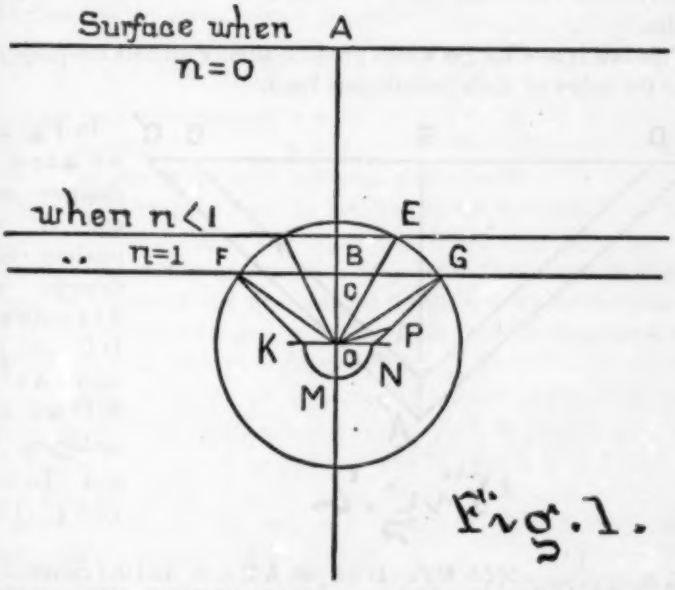


Fig. 1.

This shape is very different from a sphere, and the lengths of the radii of explosion vary in different directions. The mine's direct effect will be greatest in the direction O G, or O E.

In the figure, O A, O B, and O C are the depths, and whenever a crater is produced the depth indicates the line of least resistance.

BE or CG is called the funnel radius or the radius of lateral effect. Let r= equal the funnel radius and d = the depth, and let $n = \frac{r}{d}$, the ratio of the funnel radius and the depth, then $r = d \times n$. If $n < 1$, r will be less than d. In this case we will designate the mine as *undercharged*. If $n = 1$, r will be equal to d, and the mine will be *normal*. If $n > 1$, $r > d$, and the mine will be overcharged.

The greatest mass of water will be thrown out when the mine is *normal*, or when the depth is equal to the funnel radius. When the depth is less than r, the column of water may be thrown to a much greater height, but the mass thrown out will be less than when normal.

Dynamite and gun cotton explode much more suddenly than gunpowder and produce a greater effect when at the overcharged depth; but when at the normal or undercharged depths the phenomena produced by the three explosives differ very little.

We will take the general law for the explosion of mines in earth as applicable to submarine mines and examine the conditions of the two media.

This law is:—Charges which produce similar funnels are proportional to the cubes of their homologous lines.

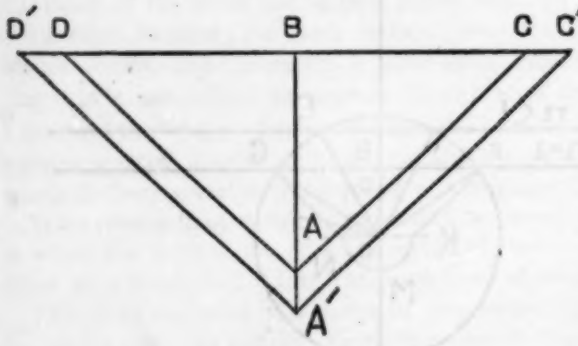


Fig. 2

In Fig. 2.—If we have two charges as A and A′ which produce similar funnels, whose diameters are D C and D′ C′, then A C and A′ C′ will be homologous lines, and $L : L' = (A C)^3 : (A' C')^3$ or $L = \frac{L'}{(A' C')^3} \times (A C)^3$. If we put A C = R, and the constant ratio $\frac{L}{(A' C')^3} = M$ we shall have $L = M R^3$, which is identical with equation (1).

But this only applies to mines which produce similar funnels, and

those in which the general conditions for the old law are complied with. This law was deduced from earth mines with slow combustion of gunpowder, and the mode of confinement exerts considerable influence. If two mines of equal charges are confined very differently the force developed will be very different; but if the confinement of each be equal, though applied in a different manner, the force developed will be equal.

The following laws for explosions of earth mines have been firmly established. In earth mines at the normal depth we have

$L_n = \frac{C}{\sqrt{8}} \times R_n^3$, where L_n = the charge, R_n = the radius of explosion and C = the coëfficient of resistance for the kind of earth.

For mines at the overcharged depth:

$L_o = Cn^3 (1.05—.05\ n)^3 \left[\frac{1}{1+n^2}\right]^{\frac{3}{2}} R_o^3$, where L_o, C, and R_o indicate the same as above, and n = the ratio of the funnel radius and the line of least resistance.

For mines at the undercharged depth:

$$L_u = C\left[\frac{4 + 3n}{7}\right]^3 \times \left[\frac{1}{1+n^2}\right]^{\frac{3}{2}} R_u^3,$$

In mines most overcharged, n = 3.

" normal, n = 1.

" smothered or most undercharged, n = 0.

From these equations we deduce the following when $L_n = L_o = L_u$ and C is constant, $R_n = 1.19\ R_o = 0.91\ R_n$ $\therefore$ $R_o < R_n < R_u$.

Therefore the radius of explosion is greater in a smothered mine and least in a mine at the overcharged depth, and the difference between the normal and overcharged mines, .19, is more than twice that between the normal and undercharged, .09.

By comparing the radii of explosion of normal and undercharged mines which are not smothered, and whose funnel radius is such that $1 > n > \frac{1}{2}$, we find for $n = \frac{1}{2}$, $R_n = .994\ R_u$, which is not very different from that when completely smothered; or $R_n = R_u \times .91$: we may therefore consider the radii of explosion of undercharged mines as practically constant for equal charges.

There is every reason to believe that a similar relation will be true for submarine mine explosions. A normal mine is regarded as a fully confined mine, and these mines develop the same force for equal charges. These may be increased if the mine becomes undercharged; but if overcharged, or at a less depth, the mine will have less confine-

ment, and develop less force and smaller radii of explosion, the decrease being considerably greater than in earth mines.

We conclude from this at once that gunpowder mines can not be used to advantage when the depth is such as to make them overcharged to any extent. Normal, undercharged, and very slightly overcharged gunpowder mines can be used advantageously in water, since their radii of explosion for equal charges are practically constant. We therefore consider the expression $L = MR^3$ also true for submarine mines. In this equation the coëfficient M varies with different explosives; but if the conditions for confinement are complied with, M may be considered constant for the same explosive within certain limits. R depends upon the charge.

The instant the mine bursts its case, the powder gases will be concentrated at the centre, whence they become disengaged on all sides. (In reality the gas is not concentrated at the centre, but as it has its greatest tension there its expansion must be assumed to begin at that point.) We then have the maximum expansion at the centre of the charge, which gradually decreases along the radius of explosion until balanced by the resistance of the surrounding mass of water.

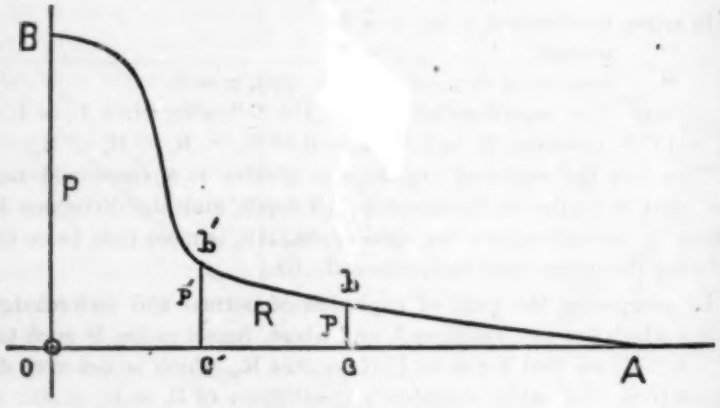


Fig. 3.

If we lay off O A = R, on the abscissas of a right angle system of co-ordinates whose origin O is the centre of the explosion, and lay off the expansion at various points as ordinates, the line joining these points will be the curve of expansion. O B = P is the expansion at

the origin while that at the extremity of the radius of explosion A = zero.

This curve can not be drawn accurately since the law of expansion has not been accurately determined; but it will be sufficient in practice to consider the maximum expansion as determined by the distance at which definite direct effects are obtained, and that the expansion gradually decreases from the centre to the extremity of the radius of explosion.

If we wish to obtain the direct effect on a ship's hull she must be within the distance R from the centre of the mine. If the surrounding resistances are equal in all directions, the destructive effect will be equal in all directions; but this is not the case in practice. We know that the direction of the explosion is perpendicular to the surface of the water because this is the line of least resistance.

It remains to be seen if it is possible to give the line of least resistance such a direction that the greatest effect may be exerted upon the object to be destroyed. In fig. 4, let O be a mine at a depth $ON = d$, SS′, the hull of a ship in such a position that $Oc = a$ is less than d; then, if we disregard the resistance of the ship's bottom, the line of least resistance will be in the direction through the bottom of the ship when a is less than the radius of explosion.

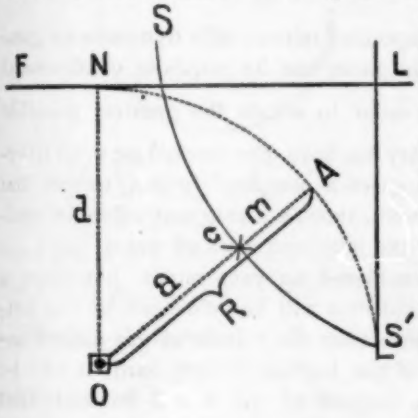


Fig. 4.

But we must take the resistance of the ship's bottom into consideration. In Fig. 3, the intensity of the expansion decreases from P at the origin to zero at A. We may then take the expansion at the point c as equal to p and regard that part of P, A c, as sufficient to breach the ship, and then this may be reckoned as the resistance of the ship, or m. Therefore a mine must be at a distance $= R - m = a$ from a ship in order to effect a breach. This distance a is called the *breaching radius*.

Since R is a measure of the explosive force, the explosion may be regarded as sufficient to penetrate a mass of water of R thickness;

and in the same way m may be regarded as equivalent to a mass of water of m thickness, the resistance of which is equal to the resistance of the ship. Therefore we can express this condition thus:—that the distance from the mine to the ship's bottom must be such that $a \leqq R-m$, and that the mine's depth d must be greater than R.

Since it will often be desirable to attack very light draught vessels it will be difficult to make $d > R$, because the depth must not be so great as to bring the ship beyond the distance $R-m$ from the mine when directly over it. If we let the ship's draught be g then $d-g$ should $= R-m$, and as light draught vessels may be very strongly built g may be taken as equal to m; whence $d=R$ and not greater than R. In this case we should have very little lateral effect, and where that is necessary the maximum will be obtained at the normal depth, or when $d = .71R$, and the value of the *breaching radius* becomes $a \leqq .71R-m$.

The above only applies to gunpowder mines; with dynamite or gun-cotton it will be sufficient if the mine has its requisite confinement and if $a \leqq R-m$; but, in order to obtain the greatest possible lateral effect, it will be necessary to have the normal or even over-charged depth. We cannot expect a complete breach unless the above conditions are complied with, though a ship may often be seriously damaged by the shock of the projected mass of water.

We have heretofore only considered buoyant mines, but when a mine rests on the bottom the explosion will be influenced by the bottom. When a mine rests on the bottom the volume of gas cannot assume the shape of a sphere; if the bottom be very hard, it will be very nearly a hemisphere, the volume of which will be such that $R'=R\sqrt[3]{2}=1.26R$. This has been demonstrated by the experiments with gunpowder; but whenever these mines produce a *crater*, the greater effects appear in the line of least resistance only, and the lateral effect is not increased.

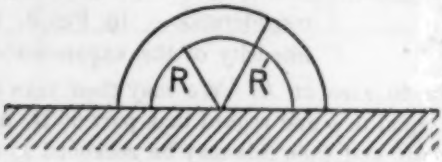


Fig. 5.

If a charge rests on the bottom, at the normal depth, the crater of

not larger than if buoyant; but it will, figuratively speaking, give a cleaner funnel. The destructive effect is especially enhanced if a ground mine is at the undercharged depth; and experience shows that the radii of explosion increase to $R'=1.26R$. With dynamite or gun-cotton the proximity to the bottom will not make so much difference, although a slight increase in the radii of explosion may be expected.

Determination of the Coefficient M.

In the equation $L=MR^3$, M must be determined by experiment for every kind of explosive. From these experiments we find that 4 lbs. of gunpowder at a depth of 4′.1 gives a funnel radius a little over 4′ and 400 lbs., 19′ deep, gives a funnel radius about 19′.

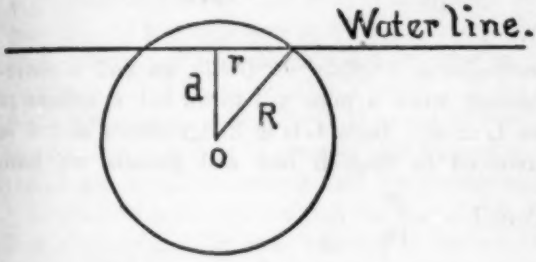


Fig. 6.

Let r = the funnel radius,
d = the depth,
R = the radius of explosion,
L = the charge and M = the coëfficient.

We have from the figure $R^2 = d^2 + r^2$ or $R = \sqrt{d^2+r^2}$ then for 4 lbs. at 4.′1 deep, $R = \sqrt{4.1^2 + 4.1^2} = 5.79'$ and 400 lbs. at 19′. deep give $r = 19$, $R = \sqrt{19^2 + 19^2} = 26.9'$.

Putting these values of R in the equation $L = M R^3 \therefore M = \frac{L}{R^3}$, we have for 4 lbs., $M = \frac{4}{5.79^3} = \frac{1}{48.5}$; for 400 lbs., we have $\frac{400}{26.9^3} = \frac{1}{48.6}$. In practice, then, we can say that $M = \frac{1}{48.6}$, and then substituting in (1) we have $L = \frac{R^3}{48.6}$; or when L is known, $R^3 = L \times 48.6$, or $R = \sqrt[3]{48.6 \times L}$: reducing we get

$$R = 3.65\sqrt[3]{L} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2).$$

This value of M is true for mines, at the normal, undercharged, and slightly overcharged depths.

In calculating the charge for mines in earth it is customary to use d in the previous equations, or the line of least resistance instead of

R. In this case, equation (1) becomes $L = \frac{d^3\sqrt{L}}{18.6} = \frac{d^3}{17}$ (3)

By comparing this with so called *average* earth it is well known that for the normal funnel $L = \frac{d^3}{10}$

Average earth has a specific gravity of 1.82
Sea-water " " " 1.03 } Laisné, *Aide Mémoire*.

The ratio of average earth and sea-water $= \frac{1.82}{1.03} = \frac{1}{1.77}$

Substituting this in $L = \frac{d^3}{10}$, we have $L = \frac{d^3}{17.7}$ which agrees very nearly with (3).

In Laisné, *Aide mémoire de l'Officier du Genie*, we find a convenient rule for ascertaining when a mine will throw out a column of water; this is put as $L = d^3$. Here L is in kilogrammes and d in metres and when reduced to English feet and pounds we have

$2.2 \times L = (3.28d)^3 \therefore L = \frac{d^3}{16}$

Another French formula makes $L = \frac{d^3}{17.9}$ and, finally, the Prussians use the formula $L = \frac{d^3}{15}$; so that from all these values we consider $L = \frac{d^3}{17}$ to be accurate for all practical purposes."

Determination of M for Dynamite or Gun Cotton.

The results of a great many experiments made in Denmark, England, Italy, and other countries were considered and from them the relative force of gunpowder to dynamite and gun cotton is found to be as 1:3 or 4; provided the mines are sufficiently confined. It is also seen that dry gun cotton is a little weaker and less sudden than dynamite. Wet gun cotton explodes more suddenly and with greater force than dry gun cotton.

"From equation (2) we have $R = 3.65\sqrt[3]{L}$ for gunpowder, or that the radius of explosion of 1 lb. of gunpowder is equal to 3.65. Comparing this with the relative force of gunpowder to dynamite we have for 1 lb. of dynamite; $1:3 = 3.65 : 3.65\sqrt[3]{3} = 5.26$

$$1 : 4 = 3.65 : 3.65\sqrt[3]{4} = 5.8$$

Therefore the radius of explosion of 1 lb. of dynamite is between 5.26 and 5.8 and we have adopted

$R = 5.5\sqrt[3]{L}$ for dynamite and

$R = 5.35\sqrt[3]{L}$ " dry and pressed gun cotton."

These values were deduced from experiments with small charges of dynamite and guncotton, and they will be further considered in the course of the experiments with larger charges.

The Least Depth of Smothered Mines.

"This is the greatest depth at which mines will be effective against large draught vessels. It will be necessary to consider this when desiring to blow up a sunken wreck, and especially when we want to have certain indirect effects which are greater from smothered mines than from mines which produce a *crater*. If the explosions were perfectly instantaneous this depth D would be equal to the radius of explosion; but it is only in practice that dynamite and gun cotton mines can be considered to explode thus instantaneously.

Explosions in earth show that the least depth for a mine not to produce a *crater* $= 1.75 \times d$, where d is the normal depth of the same charge. When R equals 1 in earth mines, we have

$$d : R : D = 0.71 : 1 : 1.24.$$

This is similarly the case in water, and some experiments made at Copenhagen in 1870 confirm this. In these

3.3 lbs. of gunpowder	were	completely	smothered	when	10′—12.3′	deep		
6.6	"	"	"	"	"	"	11.3′	"
8.8	"	"	"	"	"	"	14.4′	"
13.2	"	"	"	"	"	"	14.4′	"

the last charge being just at the limit. These results were too few and indecisive. (1)

If we take 13′.39 as a depth at which 13.2 lbs. of gunpowder will be smothered, the depths for the other charge may be deduced from the general law; so that 3.3 lbs should be 8.23′ deep; 6.6 lbs., 10.6′; 8.8 lbs. 11.63′. This would make the ratio between d, R, and D, when $R = 1$, as $d : R : D = .71 : 1 : 1.55$, or the least depth for smothered mines is a little more than twice the normal depth of the same charge. This depth is greater in ground mines than in buoyant, probably less than 2R, but if the bottom is very hard it may be equal to 2R."

THE INDIRECT EFFECTS OF MINES.

In considering this subject the report quotes from Moisson's *Etude la Question des Explosions Sousmarines.* "'From this the gases developed by a submarine explosion are found to impart a succession of shocks to a series of concentric layers of water, with a velocity of 1400 metres per second. When the shock is being transmitted, each of the successive layers is alternately compressed and rarefied, so that waves of compression and rarefaction follow each other with the velocity of the transmission, until the explosion is exhausted. Any foreign body in the water will receive a shock from the nearest compressed molecules of water. The outside molecules of the body will be compressed and transmit the wave of compression to the next layer of molecules, other impulses then quickly follow, and finally destroy the body. If the molecular action is quicker in the body than in water, the body will be merely compressed at the part attacked, if not, the impulse will be carried through the body: in neither case, however, will the body be moved.'

This explains the phenomena due to the indirect effects of an explosion, but the law for the indirect effects will have to be determined by experiment. We find the following phenomena due to the indirect effects; viz., fish are killed and stunned over a large area; electric circuit closing apparatuses are caused to make contact, mine cases are damaged and destroyed and their charges of dynamite often exploded even at relatively great distances from the centre of explosion. Ropes and electric cables are uninjured by the indirect effects, and observation proves that objects are not displaced by them. Dynamite mines explode more suddenly than gun-cotton mines and give the greatest indirect effects. Gunpowder gives the least indirect effects; but in all cases these are the greatest when the mines are smothered.

The indirect effects are very important as influencing the construction and material of mine cases and circuit closing apparatus, the disposition of dynamite in the cases, the determination of the mutual distance of mines in a system, and the use of countermines in clearing a channel. And, since fish are killed or stunned by the shock of the indirect effects, it follows that divers cannot operate when exposed to them.

The laws for the indirect effects have not been determined and they will be considered in the course of these experiments."

The Board commenced their experiments in August, 1874, made their final experiment in September, 1876, and sent in their report on

July 1st, 1877. As this board exchanged information with most of the European governments, the latest inventions up to July 1877 were duly considered by them in their report.

REPORT OF THE EXPERIMENTS.

In class A, the Board conducted a series of experiments to ascertain the best method of igniting gunpowder mines and to determine the radius of explosion of dynamite. Fifteen experiments with 112 lbs and five with 654.5 lbs of gunpowder were made. In these the mines were surrounded by empty tinned steel cylinders $\frac{1}{32}''$ thick, 10″ in diameter, and 12″ high, called *pressure cases;* and the alteration in the shape of each case was taken as an indication of the force of the explosion at its distance from the mine. These would thus measure the indirect effects, and all the igniting experiments were made with due reference to ascertaining the laws governing them.

Seven introductory experiments were made at Carlskrona with charges of gunpowder in iron cylindrical cases with convex ends; the first two were $\frac{1}{8}''$ thick, the last $\frac{1}{2}''$, and the others $\frac{1}{4}''$ thick. These had an internal capacity of 1.4 cu. ft. and were charged with gunpowder in each case.

No. 1 of 116 lbs., and No. 3 of 227 lbs were ignited by an electric igniter in a bag of gunpowder at the centre. No. 2 of 122 lbs., No. 4 of 228 lbs., and No. 5 of 231 lbs., were ignited by an electric igniter with a charge of 23 grains of fulminate at the same place. No. 6 of 247 lbs., was ignited by an electric igniter with 324 grains of dynamite and 23 gr. of fulminate. No. 7 of 444 lbs., was ignited by one electric igniter with a small charge of fulminate.

From these experiments it was found that if a powerful detonating igniter for gunpowder in very thin cases is used, the cases will be apt to burst before the entire charge is ignited; but that in cases $\frac{1}{4}''$ thick a detonating ignition may be advantageous; and that cases thicker than $\frac{1}{4}''$ will not be necessary. Three or four pressure cases were used in each of these seven introductory experiments, but as they were placed in a single line their results are not compared with others.

In each of the fifteen experiments with 112 lbs. of gunpowder, six pressure cases were placed at a depth of 9.7 feet in three lines, making an angle of 120° with each other and 20 and 30 feet from each mine. The powder used was Swedish musket, made in 1866.

CLASS A.

IGNITING EXPERIMENTS WITH 112.2 LBS. OF GUNPOWDER, 9.7′ DEEP. CARLSKRONA, 1874.

Date.	Number.	Case.	Method of Ignition.	Effects upon the Pressure Cases.						Characteristic Number.	Remarks.
				At 19.2′ from the Mine.			At 29.2′ from the Mine.				
				X	XX	XXX	X	XX	XXX		
1874. Aug. 26.	Sec. "a". 1	Steel Plate 1-16″ thick.	By 2 fuzes in the axis of the Mine.	The pressure cases at this distance were all compressed from an original height of 11.6″ to from 7.2″ to 5.9″, in all three experiments.			At this distance the pressure cases were compressed from 11.6″ to 10.6″ and 10.2″.			85	The marks X, XX and XXX, indicate the three directions, 120° apart, in which the pressure cases were placed.
Aug. 27.	2	"	By 2 fuzes along the side.								
Aug. 27.	3	"	By 10 fuzes, 2 in the axis, 8 in a spiral on the side.	The sides were badly deformed. The ends were deformed and partly severed.			Sides deformed. Ends deformed and partially severed.				The characteristic number is simply a relative number, arbitrarily using 100 as the maximum.
Sept. 2.	4	"	By means of a glass tube filled with powder and ignited by two of Ebner's Igniters.	The cases were compressed to 4.5″ and 5.1″. Sides completely deformed. Ends deformed and partially severed.			Compressed to from 10.6″ to 10.2″. Sides deformed. Ends deformed and partially severed.			100	
Sept. 3.	5	Iron Plate 1-16″ thick.	Stewart's branch tube consisting of a leaden tube covered with wire gauze, containing small igniting charges of gunpowder and two igniters.	Case compressed to a mass.	Original height retained. Sides and ends slightly deformed.	Compressed to 4″. Sides completely deformed. Ends deformed and bent in.	Original heights retained. Sides and ends slightly deformed.				No characteristic can be given for this experiment because the effects were chiefly in the direction of X.

CLASS A—c—

TABLE OF THE EXPERIMENTS FOR IGNITING 654.5 LBS. OF MUSKET POWDER.—CARLSKRONA 1875.

Date.	Number.	Method of Ignition.	Kind of case used.	Depth of the water and of the mine.	Description of the Pressure Cases and Pressure Gauges. Number and Kind.	Distance from the mine.	Depths.	Relative positions of the P. Cases and P. Gauges.	Effects on Pressure Cases. Original height. 11.69″ How Deformed.	Compressed to Each.	Mean	Effects upon the Pressure Gauges. Swedish Pressure Gauges in atmospheres. Each,	Mean	French Pres. Gauges in millimetres. Each.	Mean	Characteristic Number.	Remarks.
Aug. 7th	1	By 2 of Ebner's fuzes with an igniting charge of 385 gr'ns of powder in a tin tube.	An iron cylinder ½″ thick.	29.2′ deep in 34′ of water	3 Swedish P. Gauges.	28.2′	8.7′	X XX XXX				13 15.5 (22)	14.25				X, XX, XXX, indicate the directions in which the pressure cases and gauges run from the mine's centre; each direction was 120° from the others.
					4 Pressure Cases.	39′	15.6′	XX XXX	Sides and ends badly.	4.33″ 4.73″	4.53″	12 14.75	13.4			100	
					4 Swed'h P. Gauges	39′	30.16′	XX XXX	Completely.	3.54″ 3.54″	3.54″	13 19	16				
					4 Press. cases.	58.3′	15.6′	XX XXX	Sides and ends partially.	6.5″ 6.9″	6.7″						
					2 Swedish P. cases.	58.3′	30.16′	XX XXX	Sides very badly, one end car away	4.9″ 5.3″	5.6″	13.5 (17.2)					
Aug. 10th	2	By 2 of Ebner's fuzes with 25 grains of fulminate.	"	27.4′ in 34′ of water	3 Pressure cases.	48.5′	29.2′	X	Ends & sides badly	4.73″	4.59″	15	15			100	Mc Evoy's Circuit closer apparatus in an iron case with a wooden cover was placed at a depth of 9.7′ and 146′ from the mine. It was connected to a battery of 10 cells and a galvanometer. This explosion deflected this needle 60 degrees.
					3 Swedish P. Gauges.	"	"	XX	One end severed irregularly & badly.	3.7″		(24)					
								XXX	Completely.	3.71″		15					
					3 Pressure cases.	68′	"	X	Sides badly, ends loosened.	6.89″		7					
					3 Swedish P. Gauges	"	"	XX	Very badly, one end lost.	6.1″	6.16″	7	7				
								XXX	Very badly.	5.51″							
Aug. 12th,	3	By 2 of Ebner's fuzes with an igniting charge of .28 lbs. of powder in a glass tube.	"	"	3 Swedish P. Gauges.	29.2″	29.2′	X XX XXX				(13.5) 32.5 31.5	32				A Swedish circuit closer apparatus was placed at a depth of 9.7′ and 146′ from this mine. It was connected to a battery of 10 cells and a galvanometer, but the needle was not affected by the explosion.
					3 Pressure cases.	48.5″	29.2′	X	Sides & ends badly & irregularly. Ends loose.	4.9″		14.5		1.75			
					3 Swedish Gauges.	"	"	XX	Very badly ends loose.	5.3″	4.97″	14.5	13.9	1.75	1.83	100	
					3 French Gauges.	"	"	XXX	Almost completely.	4.73″		12.75		2			
					3 Pressure cases.	68′	"	X	Very badly. one end loosened	6.1″		6.5		0			
					3 Swedish P. Gauges.	"	"	XX	Sides & ends badly one end loosened.	6.3″	5.48″	5	62	1	1.67		
					3 French P. Gauges.	"	"	XXX	Very badly and irregularly.	3.94″		7		4			
Aug. 13th,	4	Same as that used in No. 1.	"	"	3 Swedish P. Gauges.	29.2′	29.2′	X XX XXX				29 23.25 33	32				The effects of the explosions are much smaller, owing to the powder used in the charge which was made in 1853: the powder generally used was made in 1866.
					3 Pressure cases.	48.5′	"	X	Very much.	4.53″		15.5		1.5			
					3 Swedish P. Gauges.	"	"	XX	Ends loosened.	5.1″	5.97″	15.25	15.1	0	.5	80	
					3 French P. Gauges.	"	"	XXX	Badly, one end lo'se	8.27″		14.5		0			
					3 Pressure cases.	68′	"	X	Badly, one end lo'se	8.27″		7		1.5			
					3 Swedish P. Gauges.	"	"	XX	Sides defrm'd ends loose.	9.25″	8.46″	7.5	7.25	0	.5		
					3 French P. Gauges.	"	"	XXX	Sides badly deformed, one end loose.	7.87		(13)		0			
Dec. 2.	5	By 12 fuzes in a spiral along the surface one at eve'y 3′ of the charge.	"	29.2′ in 39′ of water	Pressure cases.	48.5	29.2′	X	Sides badly, one end loose.	6.5″				1.4, 1.2, 1.1	1.23		The fuzes used had an electrical resistance of from 29,000 to 36,000 ohms. Siemens. They were ignited by Siemens' D. E. machine.
					3 Trebled French P. Gauges.	"	"	XX	Sides and ends completely.	4.33″	4.99″			1.7, 2.2, 3.5	2.47	2.16	
			"					XXX	Sides & ends & one end loose	4.13″				3. 2.9, 2.4	2.77	100	
					3 Pressure cases.	68′	"	X	Sides completely 1 end carried away.					0.2 0.2			
					5 single F. P. Gauges	"	"	XX	" "					0.9 0.9	83		
								XXX	" "					1.4			

CLASS A.—b—

IGNITING EXPERIMENTS WITH 112.2 LBS. OF GUNPOWDER, 9.7' DEEP, CARLSKRONA, 1874.

Date.	Number.	Description of Case.	Method of Ignition.	Effects upon the Pressure Cases. 19.5' from the Mine. X	XX	XXX	29.2' from the Mine. X	XX	XXX	Characteristic Number.	Remarks.
1874. Aug. 28.	Sec. "b" 1	Iron Plate ¼" thick, with a charge chamber inside, long and narrow, fitting between ends.	Musket Powder, ignited by four fuzes. One at the centre, three at the surface.	All three compressed to from 7.8" to 7". Sides badly deformed. Ends deformed and partially severed.			All three compressed to from 10.6" to 10.2" Sides and ends deformed. Ends partially severed.			80	
Aug. 28.	2	Iron Plate ¼" thick, Charge chamber at the bottom, being broad and low.	As above.	All three compressed to from 10.2" to 9". Sides badly deformed. Ends almost completely severed.			All three compressed from 10.9" to 10.2". Sides somewhat deformed. Ends deformed and partially severed.*			65	Divers picked up pieces of the mine case from which it was evident that the ¼" cases were burst, while the ½" and ¾" cases were severed at the line of rivets; pieces of these last mines were almost entire and some of the cylindrical shells were merely bulged out and not burst except at the rivets.
Aug. 29.	3	Iron Plate ¼" thick. Charge chamber in the axis, as in the first experiment.	As above.	Two cases compressed to 10.2". One case compressed to 7.8". Sides badly deformed. Ends deformed and partially severed.			Not compressed. Sides uninjured; the bottom slightly indented.			40	
Aug. 28.	4	Iron Plate ½" thick. Charge chamber at the bottom as in No. 2.	As above.	Comp. to 9.8" | Comp. to 8.6" | Comp. to 5.9" Sides badly deformed. Ends deformed and severed.			Compressed to 10.9" and 11.2". Sides slightly deformed. Bottom deformed and severed.	Comp. to 10.8" Deformed.		65	Swedish iron was used for all the cases.
Aug. 29.	5	Iron Plate ¾" thick. Charge chamber in the axis as in Nos. 1 and 3.	As above.	All three compressed to 10.6" and 10.2" Sides deformed. Ends deformed and severed.			All compressed to 10.9" and 11.4". Sides scarcely injured. One bottom slightly indented.			35	
Aug. 29.	6	Iron Plate ¾" thick. Charge chamber at the bottom as in Nos. 2 and 4.	As above.	All compressed to 10.6" and 10.9" Sides partly deformed. Ends " "			Uninjured.			30	
Sept. 1.	7	Iron Plate ½" thick. Charge chamber at the bottom.	Cannon Powder ignited as above.	All compressed to 6.7" and 7.4" Sides badly deformed. Ends deformed and severed.			Compressed to 10,9" and 10.2" Sides slightly deformed. Ends deformed and severed.			80	
Sept. 1.	8	Iron Plate ½" thick. Charge chamber at the bottom.	Cannon Powder ignited as above.	All compressed to 8.2" and 9.4" Sides and ends badly deformed. Ends entirely severed in parts.			Compressed to 10.9" Sides slightly deformed. Ends deformed and partially severed.			65	
Sept. 29.	9	Iron Plate ½" thick. Charge chamber at the bottom.	Musket Powder ignited as above.	16.6' distant. Comp. to 7.8" Sides and ends badly deformed.	24.3' distant. Comp. to 7.6" Sides and ends deformed.	19.5' distant. Comp. to 10.8" Sides partly def'm'd. Ends deformed.	26.3' distant. Comp. to 10.9" Sides and ends slightly deformed.	33.1' distant. Comp. to 11" Sides in places slightly d'form'd. Ends d'form'd.	29.2' distant, Comp. to 11.1" Sides and ends slightly deformed in parts.	70	In the ninth experiment the effects were unequal in the different directions.
Oct. 8.	10	Iron Plate ½" thick. Charge chamber at the bottom.	Musket Powder ignited by 23 grains of fulminate of mercury.	19.5' from the mine. Compressed to 7.8" & 8.4" Sides and ends badly deformed. A pressure gauge was placed under each of these three cases and indicated the following. X A little more than 10 Atmos. | XX A little more than 10 Atmos. | XXX 10 Atmos.			29.2' from the mine. Compressed to 11.1" and 11.3" Sides and ends slightly deformed.			70	In this the effects were very equally distributed.

In the next ten experiments the same size of charge and similar methods of ignition were used, and at the same time a comparison was made of the influence of the strength of cases for buoyant mines, and it was sought to ascertain the best position for the charge in its buoyant case. The charge chambers were cylinders of $\frac{1}{32}''$ steel plate of two different shapes, one being low and broad and the other high and narrow; the former kept the charge at the bottom and the latter evenly distributed along the axis of the case. Each mine was ignited by four fuzes, one at the center and three at different heights along the outer surface. See table Class A—b—

From these it is found that a charge of 112 lbs of gunpowder develops its greatest force when it entirely fills a case of steel plate $\frac{1}{16}''$ thick; also that air spaces in a mine weaken the effect. The effect decreases very much with the thickness of the case, and this, for 112 lbs. of gunpowder, must not exceed $\frac{1}{4}''$. Cannon powder was tried in the 7th and 8th experiments with about the same effect. From the results of the explosions the Board concludes that the mine cases must not be too tough, and that the joints should be as strong as the other parts of the case.

It does not make any essential difference which of the two methods is used for the position of the charge in a buoyant case.

From these results, the Board recommends a fuze composed of 1960 grains of gunpowder with two electric igniters in a glass tube at the centre of the charge, as a safe, convenient, and effective means for igniting all gunpowder mines up to 654.5 lbs. See third experiment in table Class A—c—

In class A the Board made some experiments to ascertain the radius of explosion of dynamite. They exploded fifty charges of dynamite varying in size from 4.66 lbs up to 37.4 lbs, the first series being made in 1873 with the introductory experiments. They intended to make this determination by using iron or zinc targets; but, as this method was tried in other countries and gave unsatisfactory results, they used a float of four pieces of timber enclosing a rectangular surface of water of 26.3 feet square. The charges of dynamite were suspended at different depths below the centre of the enclosed space by means of a davit on one of the floats. In the first nineteen experiments ropes were passed from the sides of the float to converge at a point over the mine; and the distance of the broken parts was taken as the extent of the direct effect in each experiment.

Seven charges of 5.7 lbs. of dynamite were exploded at depths of from 4.7′ to 11.7′.

Seven charges of 11.2 lbs. of dynamite were exploded at depths of from 8.75′ to 16.5′.

Five charges of 22.4 lbs. of dynamite were exploded at depths of from 10.7′ to 22.4′.

These explosions indicated that the direct effects of

5.7	lbs. of	dynamite	extended to a	distance of	12.7′	from the mine.
11.2	"	"	"		16.4′	" "
22.4	"	"	"		20.9	"

The cubes of these distances are as the charges, and this proves the general law previously deduced; but these distances cannot be taken as accurate lengths of the radii of explosion, because the coëfficient in the general equation $R = M \sqrt[3]{L}$ would then be 7.4, which, when compared with the coëfficient of gunpowder, would make the relative force of gunpowder be to that of dynamite as 1 : 8.2 which is contrary to experience. This is probably due to the fact that the mass of water thrown out acted as a projectile on the ropes and broke them beyond the periphery of the mine's funnel. The relative distances in these experiments, however, confirm the general law in so far as to establish that the charges vary as the cubes of these distances.

In the remaining experiments the ropes were passed parallel from the opposite sides at regular intervals of one Danish foot = 0.97 English foot. Those which were broken indicated the extent of the funnel radius at the surface. The mines were suspended at different depths below the centre as before. From these we find the following values for the radii of explosion.

4.67	lbs.	dynamite	from 4.85′	to 7.8′	deep	give R =	from 7.8′	to 8.8′
9.35	"	"	7.8′	" 9.7′	"	=	" 9.7′	" 10.7′
18.7	"	"		" 11.7′	"	=	" 12.7′	" 13.6′
37.4	"	"	11.7′	" 14.5′	"	=	" 15.7′	" 16.6′

or taking a mean, we have 8.3′, 10.5′, 13.1′, and 16.5′ as the radii of explosion for these charges respectively. These values of R vary as their cubes to the charges, and when substituted in the general equation make the coëfficient for dynamite equal to 5.5 which agrees with the previous calculation. The Board therefore concludes that the equation $R = 5.5\sqrt[3]{L}$ is true for dynamite.

If the charge L is expressed in kilogrammes and R in metres, the equation becomes $R = 2.17\sqrt[3]{L}$ kilogrammes.

CLASS B.

TABLE OF THE EXPERIMENTS MADE WITH THE SHIP FOERSIGTIGHETEN, BUILT LIKE THE IRON-CLAD HERCULES.

Date.	Number.	Weight of the charge, kind of Case, and Method of Ignition.	Position of the Mine. Depths.	Distance from the Target. Horizontally.	Distance from the Target. Actual.	Distance from the edge of the Target. From the Keel.	Target's lower edge.	Target's nearest side edge.	Draught amidships.	List to Port.	Part of the Target which was nearest the Mine.	Effects of the Explosion upon the Ship and the Target.
1874. Sept. 19.	1	32.7 lbs of Dynamite. Case of tinned steel 1-32" thick. Ignited by 1 Electric Igniter and 23 grains of fulminate.	9.3'	24.3'	25.4'				14.3'	28.3" * See Note.	Opposite the 7th Frame.	The ship received a violent shock, some of her wooden connections were broken, three rivets were loosened in the fore-and-aft bulkhead amidships, but no leak could be found by divers.
Sept. 21.	2	46.75 lbs. of Dynamite. Case and Ignition as No. 1.	9.3'	24.3'	25.4'				14.2'	25.2"	Opposite the 3rd Frame.	The ship was affected as in the first experiment. Five rivets were stripped and driven in ½". No leak of any importance could be found, but the ship made 3' or 4' of water in the space behind the target during the course of the night.
Sept. 23.	3	112.2 lbs. of Powder. In a tinned steel charge chamber 1-32" thick, enclosed in an iron case ½" thick. Ignited by 4 Electrical fuzes.	9.3'	9.75'	12' from the centre of case, and 12.2' from the centre of charge.	32.7'	26.3'	19.5'	14'	10.6"	Opposite the 5th Frame, or the centre of the target.	A large leak was found in the target above the 5th frame. The water rose quickly in the lowest compartment in the target. The ship was docked immediately. The target was indented on both sides of the centre frame, 7.8" above the water line to 8' or 9' below. The deepest indentation was 1½" deep at about 3' below the water line. The 5th frame was not buckled. 239 rivets in the outer bottom plates were stripped and broken. A great many rivets and bolts were also damaged inboards in the inner planking and the athwart ship bulkhead.
Oct. 9.	4	As in No. 1.	9.3'	14.9'	16.7'	32.7'	31'	18.3'	13.8'	24.4'	Opposite the 7th frame.	The explosion threw out a very small column of water. No leak could be found. Two rivets were broken and two were loosened in the wake of the 8th frame.
Oct. 9.	5	65.4 lbs. of Dynamite. Case and Ignition as No. 1.	9.3'	19.5'	21.1'	32.7'	35.6'	22.4'	13.8'	20.5"	Opposite the 3rd frame.	The explosion threw out a large column of water. No leak could be found. Two rivets were broken and two were loosened in the wake of the 2nd frame.
Oct. 10.	6	Charge, Case and Ignition same as in No. 1. 32.7 lbs. of Dynamite.	9.3'	10.5'	12.8'	33.1'	26.7'	14.9'	14'	18.5"	Opposite the 7th frame.	Ship trembled. Four rivets were broken and four loosened in the wake of the 7th frame. Three were broken, two loosened in the wake of the 6th frame, and some rivets were stripped and loosened between the 8th and 9th frames. A small leak was found between the 7th and 8th frames. The outer bottom was indented between the 6th and 7th, the 7th and 8th and the 8th and 9th frames. It commenced about a few inches above the water line and extended to 9.8' below. These indentations were 1½" deep forward of the 8th frame and ½" abaft this frame.
Oct. 19.	7	32.7 lbs. of Dynamite. In a case like No. 1, and ignited in the same manner.	9.3'	4.3"	4.1'	23.4'	16.8'	12.3'	14.1'	11.7"	Opposite the 4th frame.	Ship listed to starboard. Half of the space behind the target was immediately filled with water. The other half was soon filled by a leak in the centre bulkhead. The ship was docked at once. Both bottoms were breached between the 2nd and 3rd string-pieces and the 2nd and 4th frames with a hole of 51.17 sq. ft. in the inner bottom. The plates near the 4th frame near the outer bottom were broken and very much indented. But little damage was done inboards, while the fore-and-aft and the athwartship bulkheads were uninjured.
1875. Aug. 7.	8	654.5 lbs. of Gunpowder in an iron case ¼" thick. Ignited by 2 Electric fuzes with 385 grains of Gunpowder.	29.2' in 65.' of water.	21.5'	32.5'	45.9'	40.2'	36'	13.56'	17"	Opposite the 5th frame.	Ship rolled to port and was very wet inboard. The water rose 2.8" in the large space amidships and some water leaked in the target from inboard through some opened seams caused by the violence of the shock of the explosion upon the wooden hull. The iron target was uninjured. A distorted piece of the charge chamber case was found on deck.
Aug. 10.	9	18.7 lbs. of Dynamite. In a steel cylinder with convex ends. Ignited by 23 grs. of fulminate with 925.8 grs. Dyn.	9.4'	7.97'	10.46'	31.16'	24.4'	13.1'	13.64'	3.5"	Opposite the 3rd frame.	No leak of any importance could be found. The outer bottom was indented on both sides of the 3rd frame between the 2nd and 4th frames; one indentation extended down about 8' from 7.8" above the water line; the other from 2.2' above the water line to 7 feet below the water line. These indentations were 1½" and 1½" deep respectively. The plates along the 4th frame had a crack 3.9' long. One rivet was stripped.
Aug. 10.	10	As No. 9.	9.4'	-.97'	3.4'	22.1'	15.6'	8.53'	13.64'	3.5"	Opposite the 7th frame.	Ship listed to starboard and was docked. The outer bottom had an indentation 7.8' broad by 6.8' high which terminated in an irregular hole of about 23 sq. ft. This was above the 2nd string-piece between the 6th and 8th frames. The outer bottom was also indented below the 2nd stringpiece for a space 13.64' long and 4.88' wide, and had two cracks 9.7' and 12.65' long and several inches wide. The frames were bent and the 7th frame was partly carried away. The inner bottom was slightly indented and had a small crack. The target was not completely breached.
Nov. 30.	11	112.2 lbs. of Gunpowd'r. Iron case ¼" thick. Ignited by 2 Ebner's fuzes with .35 lbs. of powder in a glass tube.	10.5'	-2.8"	5.1'	22.6'	15.84'	16.4'	13.5'	13.4"	Opposite the 5th frame.	The target was found full of water five minutes after the explosion. The ship was docked at once. 35.1 sq. ft. of the outer bottom was completely carried away above the 2nd stringpiece, and the inner bottom was breached at this part slightly. Both bottoms were carried away below the 2nd stringpiece. The hole in the outer bottom measured 72 sq. ft., and that of the inner bottom 57 sq. ft. The wing passage bulkhead was bent in and broken. Some angle irons were displaced.
1876. Sept. 12.	12	654.5 lbs. of Gunpowd'r. In a steel cylinder ¼" thick, convex ends, Ignited by two Ebner's fuzes with .28 lbs. of powder in a glass tube.	29.2'	4.83'	23.55'	31.15'	27.1'	28.24'	13.4'	17.7"	Opposite the 5th frame.	The ship was lifted bodily and careened over to starboard. The iron deck was carried away and had a hole of about 100 sq. ft. The wooden deck and the ship itself was hogged. The beams were carried away and the ship's sides tumbled out so that she could not be docked. The target was completely breached, the hole in the outer bottom measured 64.6 sq ft. and that in the inner bottom was 71 sq. ft. The 6th frame was carried away and the 4th and 7th were bent. The wing passage bulkhead was bursted and stanchions and connections were knocked down. The ship was virtually destroyed.

* The list to port is given in inches, showing how many inches the starboard side was raised out of water by the list to port.

The first series proves that the depth at which a mass thrown out by an explosive loses its breaking force is 1.34 R. It was intended to prove this by experiments upon ice but opportunity failed.

Class B.

These were the chief experiments of the series, and the Swedish government placed a ship of the line, the Foersigtigheten, at the disposal of the Board for this purpose.

The ship was cut down to the line of the lower gun deck ports amidships, and nearly to the light load line at the extremities. She was 177.1′ long at the water line, 49.6′ beam amidships. The draught was 19.9′ forward and 21.4′ aft. A hole was cut out of the starboard side on both sides of the midship frame which was 31.1′ long and 24.3′ high. This hole extended from 4.13′ below the light load line to within 6.56′ of the keel. An iron target was fitted to this hole which was made in all respects like a section of the double bottom of the English ironclad Hercules. The two bottoms were 3′ apart. The plates of the outer bottom were $\frac{7}{8}$″ thick, decreasing to 13-16″ and $\frac{3}{4}$″ in the upper part. The plates of the inner bottom were $\frac{1}{2}$″ thick.

There were nine iron frames and five stringpieces between the two bottoms, the two outer frames and the highest and lowest stringpieces being at the edges of the target. The frames were numbered from forward, from No. 1 to No. 9, and the stringpieces from above, from No. 1 to No. 5. The frames were 4′ apart; the two upper stringpieces were 9′ apart and the others 4.5′ apart. The target had a centre frame with bracket plates and was made water-tight above the second stringpieces. The space between the two bottoms was thus divided into four separate water-tight compartments.

The space behind the target was closed by a vertical iron bulkhead of $\frac{1}{2}$′ plate, which was joined to two athwartship bulkheads extending from the forward and after edges of the target to the opposite sides of the ship. It was covered in by an iron deck 7-16 in. thick and was subdivided into four water-tight compartments by bulkheads in the wing passages and by athwartship bulkheads from the centre frame of the inner bottom to the fore and aft bulkhead. Iron doors were fitted to these, and man-hole plates to the compartments in the target proper, which was joined to the wooden hull by screw bolts, iron plates and angle irons. In order to make the ship resist the heaviest shocks, two rows of timbers were placed on deck to confine the ship's sides;

these ran across from side to side for the whole length of the ship. Additional supports were also given to the deck directly over the target. The hull was thoroughly caulked and six hundred and thirty water casks, of 9.34 cubic feet each, were stowed under the berth deck, in the forward and after extremities of the ship. Six pumps were fitted to the spaces in the target, and four to those behind it. Two valves were fitted to the wooden hull so that the ship could be sunk to any depth desired. The preparations were completed on the 18th of September, 1874, when the ship was taken out of the dock and anchored in the harbor of Carlskrona. The draught of the ship as here given was only when on an even keel; but when listed over to port, as was usually the case, the draught was much greater amidships.

The mines were directed so as to explode opposite the centre of the target, and as far as to the centre of the forward and after parts; and the greatest care was taken to explode them at the several distances calculated for each mine. The mines were generally suspended from a boom rigged out above the third, fifth and seventh frames, so as to be opposite the centre of the forward half, the center of the target, and the centre of the after half, respectively, as desired. In some cases the mines were suspended from hooks at the water line, and in one case it was secured to a shelf built upon the target itself.

The harbor of Carlskrona being free from currents was most favorable for the experiments. Various kinds of pressure gauges were used to ascertain the lifting force or work developed by an explosion in breaching the target. English crusher gauges were employed, similar to those used in the Oberon experiments, secured to the outer bottom of the target; they proved unsatisfactory, being too delicate to give regular indications. A style of gauge based upon the compression of spiral springs was then tried, it also proved unsatisfactory; but a modification of the French gauge invented by Captain Vavin was tolerably accurate.

Full details of these experiments are given in the following tables. Of these experiments eight out of the first ten were made with dynamite mines at a depth of 9.8′, to prove the law expressed by the equation $R = 5.5 \sqrt[3]{L}$. From these the Board concluded that the resistance of the strongest part of the target, or m, was less than 13.4′ and greater than 10.4′ in the cases where the target was breached. (No's 7 and 10).

In deducing the coëfficient 5.5 for dynamite, that for gun cotton was found to be equal to 5.35; but recent information makes wet gun-cotton quite as strong as dynamite so that the Board concluded to take a mean of these two and consider the two explosives as equal. The equation then becomes $R = 5.43, \sqrt[3]{L}$ for dynamite or gun cotton.

In the eleventh experiment the mine was suspended by a chain from a hook in the upper part of the target, with an immersion of 10.5′, and kept in this position by means of guys passed under the keel to the port side of the ship. The case was turned with its weakest part —the line of joints in the cylindrical shell—towards the target. The charge was placed in a charge-chamber, leaving a considerable unoccupied space in the mine case. Pressure cases, besides the usual pressure gauges previously mentioned, were placed around the mine in three directions to ascertain for this explosion a characteristic number such as was used in the igniting experiments. This characteristic was found to be but 50, though it completely breached the target, the loss of force being caused by the air space in the mine. The lowest edge of the breach was below the mine's centre, and the breach generally indicated that the line of least resistance passed through the outer bottom to the air space between the two bottoms, as does also the very small column of water thrown up. The target was then docked and extensively repaired, as usual after each experiment.

The twelfth experiment was made on the 12th of September, 1876, in the presence of the King of Sweden and Norway. In this, 654.5 lbs. of musket powder were placed in a buoyant case of $\frac{1}{4}$ in. steel plate fitted with an inner charge case of 1-16 inch steel plate. The case was suspended from a boom rigged out above the centre of the target and had an immersion of 29.2′. Pressure cases and gauges were suspended around the mine as before, and various kinds of empty mine cases and circuit closing apparatus were exposed in the water to give some idea of the indirect effects resulting from such a large charge. This explosion should have a characteristic of about 90.

The ship was almost completely destroyed by this explosion,—her sides tumbled out, beams and knees were carried away, and the decks were hogged so that the ship could not be docked having spread to a width greater than that of the dock gates.

The four experiments with gunpowder mines prove the correctness of the equation $R = 3.65\sqrt[3]{L}$. These experiments were made to ascertain the size of the charge that may be exploded with safety in a spar torpedo 25′ horizontally distant with 10 immersion; vide numbers 1 and

2; secondly, to prove the general law for dynamite and gunpowder; thirdly, to see what charge may be established as the minimum for contact mines;—this was shown from the tenth experiment to be not less than 18.7 lbs. of dynamite. In this an allowance is made for a distance of 3′ or 4′ owing to the difficulty of insuring absolute contact at the instant of explosion;—and finally, to ascertain the value of the resistance of a modern double bottom man-of-war in terms of the distance or the length of the radii of explosion. See table.

Class C. Experiments with Armor.

These were made at Copenhagen in December, 1874, in order to ascertain the effects on an ironclad ship's side when dynamite or guncotton mines are exploded near the surface of the water close to the armor; they would also determine the size of the charge necessary for offensive mines, such as spar, towing, and Whitehead, or fish torpedoes.

The Board made a preliminary investigation of the results of a series of experiments which had been made in Austria with plates of one square foot surface and varying thickness up to three inches. From these experiments Captain Lauer of the Austrian Engineers deduced a simple formula, according to which the charge of dynamite or guncotton necessary to breach a freely exposed plate of iron one foot square depends upon the equation $L = d^2$, where $L =$ the required charge, and $d =$ the thickness of the iron plate in inches. When the surface alters, the charge varies or $L : L' = b \times d^2 : b' \times d^2$: provided that the charge is distributed over the surface of the plate with a thickness one and a half times that of the plate, and that the dynamite has 75 per cent. of nitro glycerine and a specific gravity of 1.5.

The Board made fourteen introductory experiments to prove Lauer's formula. The charges were not distributed equally over the entire surfaces but used in cylinders, parallelopipeds, and other forms so that they might answer to the shapes of the offensive mines generally used. They were placed in paper, wooden, and tin cases, upon the plates freely exposed on the ground, or supported by a wooden foundation resting on piles driven into the ground. These experiments were made behind the breastworks of the fortifications at Copenhagen. In some cases the mines were covered by 2.3′ of loose earth, equivalent to a confinement of 1.3′ of water, because offensive mines do not explode at the surface but at some distance below.

From the first ten experiments the formula was found to indicate a greater charge than that absolutely necessary to breach. When a

CLASS C.

EXPERIMENTS WITH IRON PLATES. COPENHAGEN, 1874.

Date.	Number.	THE IRON PLATES. Thickness.	Surface of the Plate.	The Foundation.	THE CHARGE OF DYNAMITE. Weight in lbs.	Kind of Case.	Internal Dimensions of the Case.	Position of the Mine.	Confinem't.	EFFECTS.	REMARKS.
Dec. 5.	1	½"	12.36"×12.36"	11.3" freely expos'd on 2 wood beams.	.275	Paper case rectang'lar	1.03"×2.5 "×2.5"	At the Centre.	None.	Completely broken.	The cylindrical charges were placed on end in the 2d, 4th, and 7th experiments.
"	2	1"	"	"	1.1	Cylinder Paper.	2.05"×3.7" dia.	" "	"	Broken into 4 pieces.	
"	3	½"	"	Complete foundation of 6.3" timber.	1.1	rectang'lar Paper.	1.9"×3.7"×3,7"	" "	"	Breached and driven through the piles,	
8	4	1"	"	11.3" freely exposed on 2 wooden beams.	.55	Cylinder Paper.	1.3"×3.56 dia.	" "	"	Bent and breached with a star shaped hole.	Small charges of dynamite placed about 2' or 3' from the 4.4 lb. mine, were detonated by the 14th explosion.
8	5	½"	"	Bolted by 4 bolts to 8.3" timber.	.275	Rectang'lar Paper.	1.03"×2.5"×2.5"	" "	"	Bent and broken at the centre.	
"	6	1"	"	On the end of a vertical beam 8.3" thick.	1.65	"	2.14"×4.37"×4.37"	" "	"	Not breached but bent into a star shaped crack.	
"	7	1"	"	Bolted by 4 bolts to 8.3 timber.	2.2	Cylinder Paper.	2.57"×5.2" dia.	" "	"	3 pieces, timber crushed.	4 cartridges of 2 lbs. of dynamite were placed at distances of 10', 15', 20', & 25' from the 18th & 19th mines but were not affected by the explosion.
"	8	½"	"	On the end of a vertical beam 8.3" thick.	1.1	Rectang'lar Paper.	1.9"×3.7"×3.7"	" "	"	In 2 pieces, & breached. Timbers split.	
9	9	1"	"	Complete foundation of 8.3" timber.	1.65	"	2.14"×4.37" ×4.37"	" "	8.3 of earth	Broken into 3 pieces.	
"	10	1"	"	Complete foundation of 8.3" timber.	1.1	"	1.9"×3.7"×3.7"	" "	"	Bent and broken but not breached.	
10	11	½"	2.06"×2.06'	6.3" beams with the earth packed supporting foundation of 8.3" timber.	1.65	"	1.54"×5.14"×5.14"	" "	"	In 3 pieces. Foundation crushed.	5 cartridges of 2 lbs. each were exposed at distances of 10', 15', 20', 25', & 30', in the last 2 exp. but were not exploded.
"	12	1"	"	"	3.3	Rectang'lar wood'n case	2.28"×5.67"×5.67"	" "	"	In 4 pieces. Foundation crushed.	
"	13	½"	"	"	2.2	"	1.94"×5.14"×5.14"	" "	None.	Breached by a hole 9.4" in diameter. Timber broken.	
"	14	1"	"	"	4.4	"	2.64"×6.33"×6.33"	" "	"	Breached by a hole of 78 square inches.	
"	15	2"	2.06'×2.57'	Same as before with the beams resting on 4 piles 38.4"□ cross section.	8.8	"	4.28"×7.2"×7.2"	" "	"	Breached by a small hole in the centre of an indentation of 2.6 sq. ft.	
"	16	2"	"	"	8.8	"	4"×5.1"×10.2"	1 end in contact the other 3" from plate.	8.3" of loose earth	In 3 pieces. Timber foundation was crush'd	
"	17	2½"	2.28×5.6'	As no. 15, but resting on 6 piles.	1.1	"	4.23"×5.14"×5.14"	1 end 2.05," the other 5.14" from the plate.	"	Broken in 4 pieces.	
12	18	2½"	2.14'×4.63'	"	16.5	"	3.08"×8.48"×16.47"	" "	"	In 6 pieces. Foundation crushed.	
	19	5"	3.17'×4.72'	As no. 15, on 8 piles with the plate screwed to the timber.	44.	Wooden case like the Harvey	4.12"×13 38"×2.16"	1 end 2.05" the other 5.66" from the plate.	"	Bent in the middle. Foundation completely crushed.	
15	20	"	Same plate.	Placed as bent resting on 2 pieces of timber.	44	Tin cylinder.	24.72"×7.72" dia.	charge 10" from one side edge.	"	One corner broken off.	
15	21	"	Same plate.	Placed vertically as thrown.	44.	"	18.53"×8.72" dia.	Covered with 8.3" loose earth. Packed earth behind plate.	"	In 4 pieces, 2 of which were thrown to a distance of 410.	
16	22	5"	3.85'×5.64'	Resting on 8.3" timber on 4 cross pieces supported by 6 piles, and pieces of timber at the sides.	55.	Cylindro-conical case of tin.	8.13"×15.43"×5.14"	With its peak towards the centre of the plate in contact.	"	The plates were slightly bent and torn from the foundation but the foundation was not crushed.	
"	23	5"	3.47'×4.72'	"	77.	rectang'lar wood'n case	7.2"×14.4"×18.53"	At the centre in contact.	"	Split in the middle. Foundation crushed.	

charge is confined it may be reduced 25 per cent. and still give the same effect as when not confined, and again it need not be distributed evenly over the entire surface, but may be used with equal effect in various shapes. In the sixteenth, seventeenth, eighteenth, and nineteenth experiments the charge was shaped like the Harvey towing torpedo. In the twenty-second, the charge was intended to represent the Whitehead; but for convenience the case was but 8.2″ long and the cylinder 15.4″ in diameter and 5.1″ long; this brought its centre of gravity 10″ from the plate, while it is 32.5″ from the peak in the Whitehead.

These experiments demonstrate that a spar torpedo, operated from a small torpedo boat, will not seriously damage the heavily armored part of an iron-clad, because this charge will have but little confinement, and will be too small. The same is true of the Harvey and Whitehead, since their shape does not permit the charge to be brought into absolute contact. But it is also seen that the charge which will not breach will often cause serious damage by crushing in the backing of the armor and the ship's frame.

They find that Lauer's formula is generally true so that charges may be approximately deduced from $L = b \times d^2$, where b is a coëfficient depending on the surface of a plate and the support given by the foundation. In general b may be assumed as $= 3 \therefore L = 3d^2$. In this, the thickness of the charge or its measurement perpendicular to the plate must be 1.5 d for dynamite compressed to a density of 1.4, and the charge must be exploded in contact with the plate or very close to it with at least 1′ or 1.5′ immersion. The Board recommends the oblong cylindrical towing torpedo as the most favorable shape for an offensive torpedo. The resistance of plates more than 10″ thick is proportionately less and for these we may reduce the exponent of d to 1.5 and use $L = 3d^{1.5}$.

The experiments show that it will be useless to attempt to breach 5″ armor by 77lbs. of dynamite slightly confined in an offensive torpedo near the surface, since this charge did not breach this plate although it completely crushed its massive foundation. If this charge has any greater immersion, it will the more readily breach the armor, since confined charges are by so much the more powerful. A confinement of 8.3″ of loose earth = 1.3′ of immersion of water gives more than 25 per cent. greater effect; greater depths will increase this much more so that it will be perfectly useless to try to increase the resistance of a ship's bottom by any amount of armor.

Class D. The Countermine Experiments.

The Board made eight experiments in all, four with charges of 224.4lbs., and four with 448.8 lbs. of dynamite. (Four of them only are appended) and from the first four the Board arrives at the following conclusions:

1st. That the effects of countermines are greatly enhanced when at considerable depths.

2nd. That the pressure cases indicate a definite relation of the effects to the distance, which is that the charge varies as the distance raised to the 2.4 power when 9.7′ deep and to the 2.94 power when 29.2′ deep.

3rd. That the pressure gauges were too irregular to afford any means of comparison; probably owing to the fact that the shock imparted by a countermine's explosion is like a blow, while these gauges were adjusted for a gradual pressure.

4th. That the limit of the destructive effect of 448 lbs. of dynamite in the strongest kinds of cases exposed is from 175′ to 195′. In this connection it was seen that the shape of the case exercised a very important influence on its resistance to the shock of the explosion; the spherical shape is the best, but the Board recommends cylindrical cases with convex ends as very strong. Bessemer steel is also recommended as the best material for cases.

5th. That mines of dynamite can be prevented from exploding when exposed to countermines by having elastic cushions between the outer and inner cases and by packing the charge with sawdust between the cartridges and all spaces. Some experiments made in Denmark demonstrated that dynamite mines could be protected by means of water-tight wooden jackets, but the most effective means are dependent upon the distance from the countermine.

The other four experiments with countermines, made in 1875, confirmed the conclusions deduced by the Board from the first four and also established that steel plate offers the greatest resistance to countermines; that contact mines are unaffected when at a distance of 146′; that observation mines are unaffected when at a distance of 175.5′; that the double cone case is the most unfavorable shape; that the spherical case is the best shape, and that the cylinder with convex ends is practically the most suitable and strongest kind of case when the radius of convexity of the ends is at least one third the diameter of the cylinder at its base.

CLASS D.

First Experiment with Countermines. Carlskrona, September 14, 1874.

Date.	Description of the Countermine.	Depth of the Countermine.	Description of the various cases around the Countermine and their effects produced.																											
			Pressure cases ⅛″ thick, 13″ high, at a depth of 9.7′.				Pressure Gauges, 9.7 deep.				Different kinds of Cases, &c.								Loaded Mines, 9.7′ deep.											
											Position.																			
			No.	Distance.	Effects k = characteristics.		Kind and Numb'r	Distance.	Effects. Movement.	Effects. Pressure.	No.	Distance.	Depth.	Description.	Charge of Sand.	Effects.			No.	Distance.	Descript'n.	Effect.								
Sept. 14th, In the harbor of Carlskrona when the water was 32.1′ to 41′ deep.	224.4 lbs. of Dynamite containing 75 per cent. of N. G. In an iron cylinder with convex ends ½″ thick, 1.93′ high, 1.57′ diameter, having an igniting charge of .2 lbs. of dynamite and 2 fuzes of 23 grains of fulminate in each.	9.7″ deep in 38′ of water	1	43.8′	Sides partly deform'd ends driven in so as to become only 12.8″ high. k = 60.		1 Harvey bolt.	146′	III IV 5 9 12.5 mm	Absolute. 51.7 lbs	1	195′	9.7′ in 40′ of water	Iron cylinder ⅛″ thick, having a capacity for 168 lbs. in an inner zinc charge chamber.	168 lbs. of sand.	Case filled and sank. 2 rivets (inferior) were stripped, causing the leak. The spindle in the case was bent and had an indentation ⅜″		1	58 4′	Iron cylinder ⅛″ thick, having an inner charge chamber of oak, ⅛″ thick, snugly fitting outer case and containing 23.3 lbs. of dynamite packed in car tridges with sawdust.	The explosion of the countermine exploded this mine.
							2 Electro Contact lever.	195′	III IV 7 5 16.1 mm	66.6																		
			2	92.5′	Sides slightly indented about ⅛″.		3 ″	214′	III IV 6 9 14.7 mm	30 lbs. per sq. in.	2	195′	15.6′ in 41.′ of water	Iron cylinder ⅛″ thick, capacity for 654 .5 lbs. in an inner charge chamber, 1-12 ″ thick.	654.5 lbs. of sand or sawdust.	The interior of this case was damp, otherwise not affected.												
			3	13.8′	″ ″		4 ″	″	III IV 3 4 7.4 mm	15 lbs. per sq. in.																				
			4	19.5′	″ ″ also bent in ⅛″		5 ″	292′	III IV 6 10 16.2	19 lbs. per sq. in.																				
			5	24.4′	None.						3	″	41.′	Ground mine case for 654.5 lbs. of gunpowder.		Found 50 cubic inches of water in this case wh. was oth'rwise not damaged.		2	″	Iron cylinder ⅛″ thick, having an inner zinc charge case fitting with 1″ play on all sides, and supported in its place by wooden disks at the bottom and top and by staves on the sides covered with rubber 23.3 lbs. of dynamite were pack'd with sawdust in the inner case.	This was not exploded by the shock of the counter mine. Uninjured.
			6	29.2′	None.						4	″	9.7′ in 41′ of water	Swedish modification of the Chatham circuit closer connected with galvanometer.		No damage and no deflection of the galvanometer needle.												
											5	244′	24.3′ in 38′ of water	Iron cylinder case, ⅛″ thick, for 654 .5 lbs. of powder in charge case rivetted to it.	654.5 lbs. of sand.	Uninjured.												
											6	″	9.7′ in 40′ of water	Like No. 5, but capacity for 168 lbs. of gunpowder.	168 lbs. of sand.	Uninjured.												
											7	″	9.7′ in 34′	Like No 6, sides ⅛″, and ends 3-16″	″	One rivet stripped and leaking, but still serviceable.												
											8	292′	9.7′ in 32′ of water	Like No. 7.	″	Found 70 cubic inches of water in the case whch had received no injury.												
											9	″	9.7′ in 34′ of water	Sperical case, ⅛″ thick with Danish circloser apparatus.	152 lbs. of sand.	Found the case to be a trifle damp. No injury.												

Description of the Countermine.	Description of the various kinds of cases around the Countermine.																							
	Pressure Cases 13½″ high, at a depth of 9.7′			Pressure Guages.				Different kinds of Cases.										Loaded Mines, 9.7′ deep.			
	No.	Distance	Effects. k = characteristic.	No. and Kind.	Distance and Depth.	Effects. Movm't.	Effects. Pres.	No.	Position. Dist	Position. Depth	Description.	Ch'ge of Sand.	Effects.					No.	Dist.	Description.	Effect
224.5 lbs. of Dynamite in an iron cylinder with convex ends ½″ thick 1.94′ high, 1.57′ diameter, With an igniting charge of .2 lbs. of Dynamite, with 2 fuzes of 23 grs. of fulminate of mercury 29.2′ deep in 41′ of water	1	39.2′	Sides and ends c'mpl'tely deformed. Height = 8″ k = 100.	Nos. 1 and 2 Ekerman's make.	146′ from the mine, and 21.2′ deep.		Atmos. No. 1= 11⅝. No. 2 = 14.	1	146′	24.3′ in 40′ of water	Iron cylinder ⅜″ Experimental case for 654.5 lbs. of powder in an inner chamber.	6545	A little wet. Charge case dry. Sides and bottom ind'nt'd. Still serviceable.								
	2	70.8′	One side slightly indented. H'ght = 13½″ k = 35	No. 3. Ekerman's make.	194.8′ fr'm mine 7.8′ deep.		< 5 Atmospheres.	2	148′	40′	Ground mine case serving as the anchor for No. 1.	None	Case severed and broken in two. A large piece was knocked out of bott'm	1	61.5′	Iron cylinder ⅜″ th'k with an inner iron ch'rge case fitting with 1″ play on all sides held by oak staves covered with rubber. Loaded with 23.3 lbs. of dynamite packed in cartridges with sawdust.	None
	3	52.5′	Sides deformed. Ends bent in 1⅛″ sides, 4″ Height = 12″ k = 75.	No. 4. Danish Harvey Bolt.	292′ from mine, 9.7′ deep.	III. 5 10 mm.	Absolute pr's sure of 48.4 lbs.	3	150′	9.7′ in 40′ of water	Silvertown Circuit Closer Apparatus in a wooden box, connected by wires to batt'ry galvanometer, etc.	None	Galvanometer not deflected.								
	4	90′	H'ght=13½″ Bottom indented 1″ sides 13-16″ k = 15.	No. 5. Like No. 4. No. 6, do.	390′ distant and 9.7′ deep.	III. IV. 2. 8. 5.6 mm. III. IV. 2. IV. 5.4 mm.	13.06 lbs per sq. in. 11.95 lbs per sq. in.	4	190′	9.7′ in 39′ of water	Iron cylinder ⅛″ thick, with center spindle and braces screwed in and made tight by hemp packing.	165	Tight and serviceable. Spindle bent and braces torn out. Cast iron shoes bkn off	2	"	Iron case ⅛″ thick with an inner case loaded with 18.7 lbs. of dyn'mite in cartridges pack'd with sawdust in all spaces.	None
	5	138.6′	H'ght=13½″ Bottom indented ⅛″ Sides ⅝″ k = 5.	No. 7, do. No. 8, do.	585′ distant and 9.7′ deep.	III. 2 4.2 mm. III. IV. 1. 4. 3 mm.	8.24 lbs. per sq. in. 10.79 lbs per sq. in.	5	190′	21.8′ in 35′	Iron cylinder ¼″ thick. Experimental model for 654.5 lbs. of powder.	6545	Case serviceable but indented at sides. Spindle bent in.								
								6	190′	9.7′ in 39′	Iron cylinder ¼″ thick. Danish model. Wrought iron shoes. Spindle strengthened by iron bands.	165	Tight and in order.							
								7	"	9.7′ in 40′	Iron cylinder ¼″ thick, for a charge of 654.5 of powder.	654.5	Tight and in order.							
								8	"	"	Iron cylinder ⅛″ thick. For 165 lbs. of powder. Supported at centre and the sides. Oaken staves to wedge it tight.	165	Case sank. 5 rivets were stripp'd, bottom indented and joints loosened.							
								9	"	9.7′ in 35′	Spherical case iron ⅛″ thick. Experimental model.	150	In order. Bolts at j'ints loosened.							
								10	244′	9.7′ in 39′ of water	Iron cylinder ⅛″ thick. New model.	165	Two rivets stripped and case half full of wat'r, otherwise uninjured.							

CLASS D.

THIRD EXPERIMENT WITH COUNTERMINES. CARLSKRONA, OCTOBER 2, 1874.

Description of the Countermine	Description of the various kinds of Cases around the Countermine																					
	Pressure Cases, ⅛″ thick, 13½′ high and 9.7 deep.			Pressure Guages, 9.7 deep.				Different kinds of Cases.						Loaded Mines 9.7′ deep.							
	No.	Distance	Effects. k = characteristic.	No. and Kind.	Dist.	Effects. Movm't	Effects. Pres.	No.	Position. Dist	Position. Depth	Description.	Ch'ge of Sand.	Effects.	No.	Dist.	Description.	Effect
448.8 lbs. of dynamite, 75 per cent. of Nitro Glycerine in an iron cylinder with c'nvex ends ⅛″ thick, 2.43′ high, .2′ diameter. With an igniting ch'ge of .2 lbs. of dynamite with 2 fuzes of 23 grs. of fulminate each. 9.7′ deep in 37′ of water.	1	48.5′	Bursted and sunk.	1 Ekerman's.	97.3′		Atmos. 12½	1	149′	9.7′	Silvertown Circuit C'ser in an ir'n case ⅛″ thick with a wooden jacket. Connected with galvanometer, etc.	None	Damag'd Needle deflected to 15°	1	58.4	A Pressure Case of ir'n ⅛″ thick. Loaded with 37.4 lbs. of gunpowd'r and fitted with a service fuze.	Not exploded Sides defo'med like the 3d pressure case in this experiment. Sides bent in 1 13-16″ Bottom bent in ⅞″ Height unaltered.
	2	58.4′	Sides very much deformed. Sides bent in 1¾″ Ends bent in 1½″ Height = 13 1-16″ k = 68.	2 do.	149′		9¾										
				3 do.	196′		5										
	3	68.2′	Sides deformed, bent in 1 7-16″ Ends bent in 1⅝″ Height = 13¾″ k = 40.	4 Bolt of the Harvey To'p'do	389′	III. IV. 3. 5. 7.8 mm.	Absolute. 41.8 lbs.	2	389′	39′	Danish polarized relay on the bottom.	None	In order.	REMARKS.				
	4	78′	Sides slightly deformed and bent in 1 3-16″ Ends bent in 1 1-16″ Height = 13 5-16″ k = 25.	5 Danish Harv'y Bolt	487′	IV. 10 1.8 mm.	8.24 lbs. per sq. in.	3	,,	at the surface nearly.	Danish Harvey Case. Iron Case with wooden frame at the sides & bottom.	Fill'd with sand and sawdust.	Uninjured.	The countermine was anchored by a 1000 lb. mushroom anchor. The explosion forced this anchor 12′ into the bed of the harbor, which was of blue clay with 1′ or 2′ of mud over it. It required a force of 6500 lbs. measured by a dynamometer to raise this anchor and two chain straps ⅝″ broke in the effort to do so.				
				6 do.	"	"	9.37 lbs. per sq. in.										
	5	97.3′	Sides not deformed. Bent in 9-16″ Ends bent in ⅛″ Height unaltered. k = 5	7 do.	682′	IV. 7. 1.2 mm.	7.67 lbs. per sq. in.	4	"	"	Swedish H'rv'y case in a wooden box.	"	"				
				8 do.	"	IV. 3. .9 mm.	8.24 lbs. per sq. in.										

CLASS D.

FOURTH EXPERIMENT WITH COUNTERMINES. CARLSKRONA, OCTOBER 13, 1874.

Description of the various kinds of Cases around the Countermine.

Description of the Countermine.	Pressure Cases, ⅛ thick, 13.5 high and 9.7 deep.			Pressure Guages 9.7 deep.				Different kinds of Cases.						Loaded Mines 9.7 deep.			
	No.	Distance	Effects. k = characteristic.	No. and Kind.	Dist.	Effects. Movm't	Effects. Pres.	No.	Position. Dist	Position. Depth	Description.	Charge of Sand	Effects.	No.	Dist.	Description.	Effect
448.8 lbs. of Dynamite of 75 per cent. nitroglycerine in an iron cylinder with convex ends ⅛" thick, 2.43' high, 2' in diameter with an igniting charge of .2 lbs. of dynamite with 2 fuzes of 23 grains of fulminate each. 29.2' deep in 40' of water.	1	49.3'	Sides pressed together and badly deformed. Bottom loosened and distorted. Head irregularly deformed. Height = 10" k = 97	No. 1 Ekenäs 9.	97.3'		Atmospheres. 12	1	175'	9.7' in 28' of wat'r	Iron sphere ⅜" thick.	150 lbs.	Case serviceable but had about 2 qts. of water in it. One bolt at the joints broken, solder loosened. Case but little indented.	1	58'	Pressure case of iron ⅜" thick load'd with 23.3 lbs of wet gun cotton with 28 per cent. of moisture with an igniting charge of 1.5 lbs. of dry gun cotton in a tin case with 23 grains of fulminate.	Case sank but was not exploded. Bott'm was badly bent in, sides partially deformed. Height = 12¾". The fuze case was badly bent.
				2 do.	146'		Atmos. 9										
				3 do.	195'		" 7⅜										
	2	68.1'	Sides badly deformed and pressed together. Bottom knocked out. Top bent in 2¼" Height = 12⅛" k = 85	4 Danish bolt	389.2	III IV 2—2 4.5 mm.	11.2 lb. per sq. in.	2	"	9.7 in 28' of wat'r	Iron cylinder ½" thick. Swedish model.	165 lbs.	Case serviceable but had a little water in it. Sides unaltered & tight, the bottom was loose. Spindle & braces bent. All cast iron shoes were loosened.				
				5 do.	"	III IV 2—2 4.2 mm.	11.36 lb. per sq. in.										
				6 do.	584'	III IV O—7 1.2 mm.	7.67 lbs. per sq. in.										
	3	89.5'	Sides partly deformed. Head bent in 1 15-16" Bott'm bent in 1" Height = 12⅞" k = 68	7 do.	"	1 III 2.1 mm.	7.67 lbs. per sq. in.	3	195'	40'	Cast Iron Ground mine. Swedish model.		Broken badly with the bottom severed at the joints.				
	4	113'	Sides but slightly & partially deformed. Head bent in 2". Bottom bent in 1⅛ Height unaltered k = 25.					4	"	2'	Danish Harvey Case.	Sawdust.	Leak in the filling hole—uninjured.				
	5	146'	Sides & Height unaltered. Head bent in 1¾" Bottom bent in 1" k = 10					5	"	"	Swedish do.	"	Uninjured.				
								6	292'	40	Relay case Danish.		In order after the explosion.				

CLASS D.

FIFTH EXPERIMENT WITH COUNTERMINES. CARLSKRONA, AUGUST 16, 1875.

Description of the various kinds of cases around the Countermines.

Description of the Counter-termine.

244.4 lbs. of dynamite, 75 per cent. Nitro-Glycerine. In an iron cylinder with convex ends ⅜" thick 23" high, 19" diameter, with igniting charge of 2 lbs. of dynamite with 2 fuzes of 23 grs. of fulminate each. 9.7' deep in sea water

Pressure Cases, ⅜" thick, 13.5" high, 9.7' deep.

No.	Distance	Effects. k = characteristic.
1	39'	Sides deformed sides indented 1.58", Bottom indented, 1.25" Height=12.56" k=60.
2	48.7'	Case partly deform'd sides indented, 1.35" Bottom indented .97" Height unaltered k=40.
3	58.4'	Sides slightly deformed, sides indented .94" Bottom indented .67" Height unaltered, k=20.
4	68'	Not deformed, Sides indented 47" Bottom indented .47" Height unaltered k=3.
5	78'	Not deformed, Sides indented 1 13" Bottom indented .51" Height unaltered k=8

Pressure Gauges.

Kind and Number.	Dist.	Depth.	Effects Indicated.
Swedish			Atmospheres
No. 6	39'	9.7'	(24)
" 7	"	"	6
" 1	"	29.2'	10
" 3	58.4'	9.7'	0
" 8	"	"	0
" 2	"	29.2'	5
" 4	78	9.7'	5
" 5	"	"	2
" 9	"	29.2'	22
French			Compression
No. 1	39'	9.7'	9 m.m. =.35"
" 4	"	29.2'	10.5 " =.41"
" 6	58.4'	9.7'	4 " =.16"
" 2	"	29.2'	6 " =.24"
" 5	78'	9.7'	3.25 " =.13"
" 3	Omitted.		

Different kinds and shapes of Cases.

No.	Distance	Depth.	Description.	Charge of Sand.	Effects.
1	146'	9.7' in 39' of water	Steel cylinder 3-16" thick with convex ends, having an inner charge chamber fitted for a charge of 164 lbs., and filled with sawdust, and a Silvertown Circuit Closer connected with galvanometer, etc. Board's Model, 1875.	164 lbs of sand and sawdust.	Case uninjured. Galvanometer needle not deflected.
2	"	29.2' in 39' of water	Steel cylinder ¼" thick with convex ends, with an inner cylindrical case of steel 1-16" thick, for 654.5 lbs. of powder, case filled with sand and sawdust. This was anchored by a ground mine case filled with water.	654 5 lbs of sand and sawdust.	Case uninjured.

No.	Distance	9.7'	Experim'ntal shapes of steel cases 1-16" thick, with a vol'me =1220 cu. in.	Ratio betw. the height and diameter of convex ends.	Effects.
1	68'	9.7'	Cylinder with convex ends.	.16	One side slightly indented, one indentation in the top, two in the bottom.
2	"	"	"	.22	Slightly deformed, with the joints loosened at one part of the top.
3	"	"	"	.28	Top severed and crushed in, slightly deforming the sides.
4	"	"	"	.33	One side slightly indented.
5	"	"	Like the steel case described ab've with the Circuit Closer.	.39	" "
6	"	"	Double cone with spherical ends.		Sides deformed. Larger sphere at the top was broken out. Lower sphere unaltered.
7	"	"	Steel sphere ¼" thick (could not make steel sphere 1-16" thick.)		None.

CLASS D.

SIXTH EXPERIMENT WITH COUNTERMINES. CARLSKRONA, AUGUST, 18, 1875.

Description of the various kinds of cases around the Countermines.

Description of the Countermine.	Pressure Cases, ⅛″ thick, 13.5″ high, 9.7′ deep.			Pressure Gauges.				Different kinds and shapes of Cases.					
	No.	Distance	Effects. k = characteristic.	Kind and Number.	Dis'.	Dep'	Effects Indicated.	No.	Distance	Depth.	Description.	Charge of Sand or Sawdust.	Effects.
224,4 lbs. of dynamite, 75 per cent. of Nitro glycerine in an iron cylinder ⅛″ thick, 23″ high, 19″ diameter. With an igniting charge of .2 lb. of dynamite with 2 fuzes of 23 grains of fulminate each. 29.2′ deep in 38 of water.	1	39′	Badly deformed. Top knocked in and broken. Bottom severed and bent. Height = 11.97″ k = 90.	Swedish.			Atmospheres.	1	146′	9.7′ in 37′ of wat'r	Steel cylinder 3-16″ thick with convex ends, having an inner charge chamber for 164 lb charges, filled with sawdust, and fitted with Silverton Circuit closer, galvanometer fuze etc., Boarts Model, 1875.	164. lb. of sand & sawdust.	In order. Circuit closer apparatus was not affected.
				No. 8.	39′	9.7′	11.5						
				" 1.	"	29.2′	19						
				" 2.	"	"	27						
				" 5.	58.4′	9.7′	9						
				" 3.	"	29.2′	15						
				" 4.	"	"	18						
				" 6.	78′	9.7′	7						
				" 7.	"	29.2	9.5						
				" 9.	"	"	(17)						
	2	48.7′	Badly deformed Sides indented 2.13″ Bottom knocked in Height = 12.36″ k = 80.	French.			Compression.						
				No. 4.	39′	97	12.25 mm.=.48″						
				" 1.	"	29							
				" 6.	58.4′	9.7′	7 = .27″						
				" 3.	"	29.2	8.75=.34″						
				" 5.	78′	9.7′	4 = .16″						
				" 2.	"	29.2	8=.32						
	3	58.4′	Deformed. Sides indented 1.55″ Bottom knocked in. Height unaltered. k = 65.					2	"	29.2′ in 37′ of wat'r	Steel cylinder ¼″ thick with convex ends, and an inner steel case 1-16″ thick, fitted for 654.5 lbs. charge filled with sand and sawdust. Anchored by a ground mine case filled with water.	654.5 lbs of sand and sawdust.	Half full of water— charge case damp. Sides indented near the ends ⅛″ deep, 3″ long. An indentation on the bottom 7″ long—5″ broad and ¼″ deep. Joints in the cylindrical part were loosened, iron bands were bent and the mooring chain damaged.
	4	68	Not deformed. Sides indented 1.26.″ Bottom indented. 1.06″ Height unaltered. k = 20.										

No.	Distance	D'pth	Experimental shape of steel cases 1-16″ thick with a volume = 1,220 cub. in.	Ratio of the height & the diameter of the ends.	Effects.
4	68	9.7′	Cylinder with convex ends.	.33	Sides rather badly deformed, along the joints of the ends. Bottom unaltered except that due to the sides being crushed.
5	"	"	Like the steel case described above with cir. closer.	.39	" "
6	"	"	Doubled Cone.		Badly deformed.
7	"	"	Steel sphere ⅛″ thick.		None.

CLASS D.

SEVENTH EXPERIMENT WITH COUNTERMINES. CARLSKRONA, AUGUST 24, 1875.

Description of the various kinds of cases around the Countermine.

Description of the Countermine.	Pressure Cases, ⅛″ thick, 13.5″ high, 9.7′ deep.			Pressure Gauge.				Different kinds and shapes of mine cases.					
	No.	Distance.	Affects. k = characteristic	Kind and Number.	Dist.	Depth.	Effects Indicated	No.	Distance	Depth.	Description	Charge of Sand or Sawdust.	Effects.
448.8 lbs. of Dynamite of 75 per cent. of Nitro-Glycerine. In an iron cylinder with convex ends ½″ thick 29.1″ high 24.4″ diameter, with an ignition charge of 2 lbs. of dynamite with 2 fuzes of 23 grains of fulminate each. 9.7′ deep in 39′ of water.	1	48.7′	Badly deformed, sides indented 2.2″ and split. Bottom knocked in and half severed. Height=12.5″ k=85	Swedish. No. 1.	48.7′	9.7′	Atmospheres. 10	1	146′	9.7′ in 39′ of wat'r	Steel cylinder 3-16″ thick with convex ends, having an inner charge case for 164.4 lbs. of charge and fitted with the Silvertown circuit closer, galvanometer fuze, etc., case filled with sand and sawdust, Brush's Model, 1875.	164.4 lbs of sand and sawdust.	Case in order. Circuit closer did not make contact.
	2	58.4	Deformed most on one side, indented 1.4′ Bottom knocked in and partly severed. Height=12.9″ k=65.	" 2.	"	"	15						
				" 5.	"	29.2′	16						
				" 3.	58.4′	9.7′	5¾						
				" 4.	"	"	9						
				" 7.	"	29.2	15						
				" 6.	78′	9.7	7						
				" 9.	"	"	(9)						
				" 8.	"	29.2	6¾						
	3	63′	⅔ of the shell of the case deformed. Indented 1.32″ Bottom partly severed. Height unaltered k=60.	French. No. 2.	48.7′	9.7′	Compression. 14.75 mm.=.58″	2	175.5′	29.2′ in 38′ of wat'r	Steel cylinder ¼″ thick, with convex ends, having an inner steel charge case 1-16″ thick armored by means of a ground mine filled with water. Capacity of this case was 654.5 lbs., and was filled with sand and sawdust.	654.5 lbs of sand and sawdust.	In order.
				" 4.	"	29.2	17 " =.67″						
				" 3.	58.4′	9.7	8 " =.32″						
				" 5.	"	29.2	13.25 " =.52″						
				" 1.	78′	9.7	5 " =1.97″						
				" 6.	"	29.2	8.75 " =.34″						
	4	78′	Not deformed. Indented .93″ Bottom loosened. Height unaltered k=10.										
	5	97.4	Indented .68″ Bottom loosened Height unaltered k=8.										

No.	Distance	Depth.	Experimental shapes of steel cases.	Ratio of the height of ends to diam'r of base.	Effects.
1	48.7′	9.7′	Steel sphere ⅜″ thick.		None, except that the stopper of the filling hole was driven in.
2	78′	"	Like the case described above fitted with the Silvertown circuit closer.	.39	Sides deformed along the upper edge. Top partly sundered, bottom unaltered.
5	97.4′	"	"	"	Sides slightly deformed. The convex top was slightly indented at one place. Bottom unaltered.

CLASS D.

EIGHTH EXPERIMENT WITH COUNTERMINES. CARLSKRONA, AUGUST 27, 1875.

Description of the various kinds of cases around the Countermine.

Description of the Countermine.	Pressure Cases ½" thick, 13.5 High, 9.7 deep.			Pressure Gauges.				Different kinds and shapes of mine cases.					
	No.	Distance	Affects. k= characteristic.	Kind and Number.	Dist.	Depth.	Effects Indicated.	No.	Distance	Depth.	Description.	Charge of sand.	Effects.
448.8 lbs. of Dynamite of 75 per cent. of nitro glycerine. In cartridges of 1 and 2 lbs. packed in an iron cylinder with convex ends. ⅛" thick, 29.1" high 24.4" diameter. With an igniting charge of .2 lb. with 2 fuzes of 23 grains of fulminate each. 29.2' deep in 39' of water.	1	48.7'	Bursted and lost.		Swedish.		Atmospheres.	1	146'	9.7' in 39' of wat'r	Steel cylinder 3-16" thick with convex ends, fitted for 164.4 lbs. charge and Silvertown Circuit closer like those used in the three previous experiments.	164.4 lbs. of sand and sawdust.	Case uninjured but the shock of the explosion ignited the fuze.
	2	58.4'	Top indented. Bottom knocked in. Sides slightly deformed. The effects were abnormal and different from all other experiments.	5	48.7'	9.7'	18						
				1	"	29.2'	18						
				2	"	"	25						
				8	58.4'	9.7'	9.25						
				3	"	29.2'	25						
				4	"	"	28.5						
				7	78'	9.7'	8.25						
				6	"	29.2'	16.5						
				9	"	"	(25.5)						
	3	68'	Deformed most on one side. Top indented 2.14" from centre indented 1.56" and partly covered. Height = 12.9" k = 95.		French.		Compression.	2	175.5	29.2' in 39' of wat'r	Steel cylinder ¼" thick with convex ends, having an inner steel case 1-16" thick for a charge of 654.4 lbs of powder. Like those used in the three previous experiments.	654.4 lbs. of sand and sawdust	Uninjured.
				4	48.7'	9.7'	11 mm. = .43"						
				2	"	29.2	18.5 " = .73"						
				6	58.4	9.7	11.5 " = .45"						
				3	"	29.2	19 " = .75"						
				5	78'	9.7	3.75 = .14"						
				1	"	29.2	(36 ") = 1.42"						
	4	78'	Sides deformed and flattened a little. Top indented 1.56" and cracked. Bottom knocked out. Height = 12.8" k = 75.					No.	Distance	D'pth	Experimental shapes.		Effects.
								1	48.7'	9.7'	Steel sphere ⅛" thick.		The upper half of the case was indented in three places of which one is laminated in a star shaped breach.

Remarks.

The effects of the explosion of this mine were very irregular since some of the pressure cases and pressure gauges indicated relatively greater effects at greater distances, being in this respect quite different from the other experiments.

This finishes the account of the experiment. In the official report of the Scandinavian Board, the results of these experiments are discussed at length from which I will simply give the most important facts under heads of explosives and their ignition; the effects of mines; materials, construction and application of mines.

Explosives And Their Ignition.

Gunpowder, dynamite, and compressed gun cotton may be used in submarine mines; musket or cannon powder may also be used, but it should be of recent make. The powder used in these experiments had a density of 1.6 to 1.88 and a gravimetric density of .90 to .94, the weight of one cubic foot being equal to 5.75 lbs.

Charges up to 1000 lbs. will be satisfactorily ignited by a single fuze at the centre of the charge; but to insure the ignition of the entire charge a fuze is recommended, consisting of a glass or zinc tube containing 1500 to 2000 grains of musket powder and two electric igniters in the center of the charge. Two fuzes are recommended for charges exceeding 1000 lbs., and three for more than 2000 lbs., each one being arranged to ignite an equal portion of the charge.

The Board made use of normal dynamite with from 72 to 75 per cent. nitro-glycerine and 25 to 28 per cent. of Kieselguhr. The explosive force is expressed by the breaching of a ½" plate of the best Lowmoor iron by 2823 to 3086 grains unconfined. It may be used in one pound cartridges or as loosely mixed dynamite; the latter has about the same density as gunpowder. 50.5 lbs. of dynamite in one pound packages has a volume of one cubic foot. Cartridges in very thin paper cases weigh 87 lbs. to the cubic foot when not frozen. The ignition is independent of the size of the charge, but the most convenient method is by a detonator of about 23 grains of fulminate of mercury in contact with the dynamite; an electric igniter with two detonating cartridges may be advisable with large charges.

The gun cotton was furnished by Professor Abel in compressed cylindrical discs weighing .596 lbs. each with a density of 1.1. One cubic foot weighs 56.64 lbs. If moistened with 20 or 30 per cent. of water, gun cotton is not at all dangerous and must be exploded by the detonation of an igniting charge of dry gun cotton, the latter being ignited by one or two fuzes of 23 grains of fulminate of mercury. This igniting charge should be 1.1 lb. for a charge of 220 lbs and 2.2 lbs. for larger charges. The guncotton must be wet with fresh water;

if it is exposed to the action of salt water for a very long time it must be dried again before it can be exploded.

[This statement is not made by any other authority.] The explosive force is practically equal to that of normal dynamite and the relative force of the two gunpowder is for gunpowder as 1—as 1 : 3 or 4, if sufficiently confined.

The Effects of Mines.

The experiments have demonstrated the practical accuracy of the equation $L = MR^3$ and $R = K\sqrt[3]{L}$ when $\sqrt[3]{M} = \frac{1}{K}$ or $K = \frac{1}{\sqrt[3]{M}}$

The values of M and K were determined in the theoretical deductions and proven by the experiments $M = \frac{1}{48.6}$ and $K = 3.65$ for gunpowder, and $M = \frac{1}{160}$ and $K = 5.43$ for dynamite which substituted give these two general rules,

$L = \frac{R^3}{48.7}$ and $R = 3.65\sqrt[3]{L}$ for gunpowder

and $L = \frac{R^3}{160}$ and $R = 5.43\sqrt[3]{L}$ for dynamite,

from which we can deduce the charge, or R, for buoyant mines. If a ground mine rests on a rocky bottom, R will be one third greater in the line of least resistance, but only one tenth greater if the bottom is soft or muddy. If the mine is loaded with dynamite or guncotton the bottom will have no effect.

The minimum depth at which this equation holds true for gunpowder mines is when $d = 0.6R$; and R has its greatest value when $\frac{d}{R} = .65$ to .71, or when at the normal depth. The minimum depth for dynamite mines is 0.5R.

The maximum depth is equal to R for dynamite mines, and for ground mines of gunpowder; and to .9R for buoyant gunpowder mines if any lateral effect whatever is desired. The bottom of a vessel drawing 16′ of water—this being taken as the lightest draught of a vessel built like the ironclad Hercules—will be at least 16′ within R when directly over the mine, and this is sufficiently near to effect a complete breach.

The Board make a number of deductions from a series of experiments collected from different countries besides their own, from which

the resistance of wooden ships, gunboats, et cet., is found to be equal to from 1.3 metres to 1.7 metres; or for wooden ships generally, $m = 6.56'$. We find from these that the resistance of a ship like the Hercules is equal to 13.12′, since it was breached when this distance within the radii of explosion and was not breached when further off. In the same way, the resistance of the outer bottom was found to be equal to 9.84′; so that if we denote the breaching radius by B and the radius of explosion by R as usual, we have the following expressions for the distances at which different kinds of ships may be breached. Wooden or thin iron ships (single bottom) $B = R - 6.56'$. Stronger iron ships (single bottom) $B = R - 9.84'$. Heavy double bottom ironclads like the Hercules $B = R - 13.12'$.

It is also necessary to know the relative position of the mine to the part of the ship to be breached. Theoretical consideration and direct experience demonstrate that a ship will be breached only when exposed to the direct effects; that is, when in the sphere of the funnel. This funnel may be considered as a cone with its base at the surface, and with an angle $= (2\alpha,)$ at the vertex. The value of this angle can only be given by experience, and this angle will determine the horizontal distance of the lateral effect. If the crater were a sphere, the angle 2α could be readily determined by $\cos \alpha = \frac{d}{R}$; but this is only the case when d is the normal depth, and this must be taken as the maximum value of the angle 2α. The results of the collected experiments give the following values for half the angle at the vertex; For buoyant gunpowder mines.

At the depth of normal mines $\alpha = 45°$; when $d = .71R$.
At the depth of overcharged mines $\alpha = 53°$; at the minimum depth, $= .6R$.
At the depth of undercharged mines $\alpha = 23°$; when $d = .9R$.

For ground mines of gunpowder,

At the depth of a normal mine $\alpha = 40°$; when $d = .71R$.
At the depth of an overcharged mine $\alpha = 45°$; when $d = .6R$.
At the depth of an undercharged mine $\alpha = 25°$; when $d = .9R$.
or $\alpha = 23°$; when $d = R$.

For dynamite or guncotton mines.

When buoyant or ground $\alpha = 45°$; when $d = .7R$.
When buoyant $\alpha = 60°$; $d =$ minimum $= .5R$.
When ground $\alpha = .55$ to $60°$; $d =$ minimum $= .5R$.
At the maximum depth $\alpha = 20°$; when $d = R$.

THE HORIZONTAL DISTANCE OF THE MINE'S LATERAL EFFECT.

This is the same as the funnel radius previously mentioned and it depends upon the value of the angle a. In fig. 7 let VL be the surface of the water. M = a mine at the depth M A = d.

A M C = half vertical section of the cone of explosion, A M C = a = half the angle at the vertex. MC = R = the radius of explosion cos. $a = \frac{MA}{MC} = \frac{d}{R}$ A C = r = the funnel radius at the surface of the water.

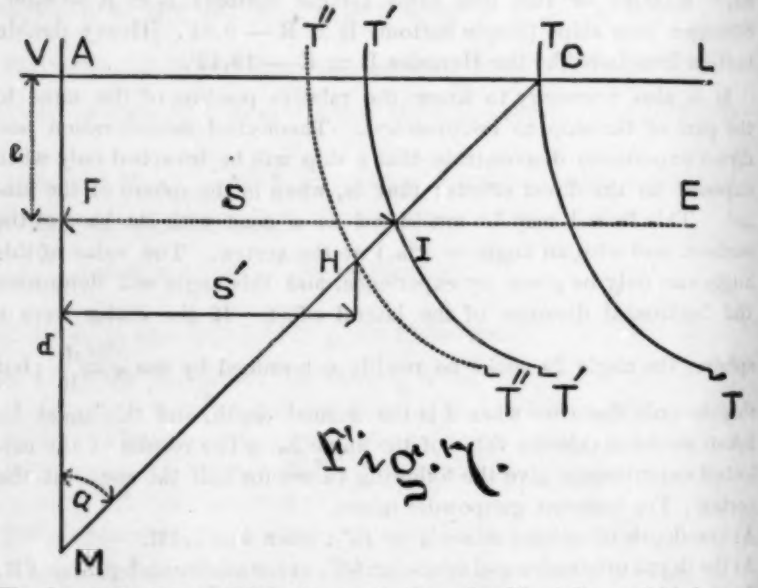


Fig. 7.

The least depth at which the explosion should strike a ship is e or 9'.84 for the heaviest ironclads. If a ship's hull T T of m resistance reaches the point C it will enter the sphere of effect and will be breached when it reaches the point I, if M I $\lessgtr$ B, the breaching radius. If MI > B and B = M H the hull will not be breached until it reaches the point H or takes the position T'' H T''. In the first case M I $\lessgtr$ B, the horizontal distance of the lateral effect, or S, will be determined by the line F I = S = $(d-e)$ tan. a; in the other case M H = B by S' = B sine a. If M I = B, then S = S'.

Nine graphical illustrations are given to illustrate the relation of

the depth to charges of from 300 to 1000 kilogrammes of gunpowder and from 100 to 500 kilogrammes of dynamite. From these they find no essential difference in the extent of the lateral effect between mines at the minimum and normal depths, so that the last depth should be generally preferred.

A given charge of gunpowder has its greatest lateral effect at small depths, when buoyant.

If great lateral effect is desired, as with observation mines, it will generally be advisable to use gunpowder charges in buoyant mines; with dynamite, buoyant or ground mines may be used with equal effect.

The size of the charges in service may be determined by aid of the given rules when not indicated by experiment. Contact mines with 9′ or 10′ immersion should have a charge of 22 lbs. of dynamite in order to breach completely a vessel with a bottom like the Hercules, if in absolute contact or within 1′ or 2′ of the bottom; but since absolute contact cannot be always obtained, they recommend 33 lbs. of dynamite or 110 lbs. of gunpowder which when exploded will make a complete breach even when 3′ or 4′ from the ship. This charge will then cause such serious damage to an enemy's ship that she will only be saved from sinking by a most thorough system of water-tight bulkheads, and even then she will most likely be obliged to withdraw from action as disabled. This charge is therefore recommended for all offensive mines.

The charge for large contact mines 10′ to 13′ deep should be large enough to sink an enemy's ship inevitably; but this explosion should not be so great as to affect neighboring mines in a system. In view of this the Board recommends charges of 110 lbs. of dynamite for these mines, which will have sufficient confinement at depths of from .4 R to .5 R. This charge is equivalent to 363 lbs. of gunpowder which would be very much overcharged for this depth, and therefore a considerable amount of force would be lost, and the ship might not be destroyed. If we use gunpowder the charge should not exceed 220 lbs., and the depth should be at least 13′.1, since $\frac{d}{R} = .6$. We can place gunpowder mines closer together in a system of defence than dynamite mines, though the enemy can destroy gunpowder mines with less danger.

To avoid large charges the depth should not be greater than necessary. If we have a choice, the depth should be such that the largest ships may pass over them without touching and this is assumed to be

28.5′ for most cases. The smallest charges are those deduced from .9 R = 28.5′ for buoyant gunpowder mines and R = 28′.5 for ground gunpowder mines and dynamite or guncotton mines. Substituting these values of R in the general equation $L = M R^3$, we have for buoyant gunpowder mines:

$$.9\ R = 28.5', \text{ or } R = 31.7' \therefore L = \frac{1}{48.6} \times 31.7^3 = 655.42 \text{ lbs.};$$

for ground mines:

$$R = 28.5' \therefore L = \frac{1}{48.6} \times 28.5^3 = 440.1 \text{ lbs.};$$

for dynamite mines:

$$R = 28.5' \therefore L = \frac{1}{5.43^3} \times 28.5^3 = 149.66 \text{ lbs.}$$

These charges give very small lateral effects as determined by S = (=R—m) sine α; so that for $m = 13.1'$, we have respectively; for the above charges and depths,

S = (31.7′—13.1′) sine 23° = 18.6 × 0.39 = 7.15′.
S = (28.5′—13.1′) sine 25° = 15.4 × .423 = 6.51′.
S = (28.5′—13.1′) sine 20° = 15.4 × .324 = 4.989′.

If there is any current allowance will have to be made for a probable change of position and errors of observation, which should equal one half the ship's beam.

The greatest charge that may be used is determined by 0.6 R = 28.5′ for buoyant gunpowder mines and 0.5 R = 28.5′ for dynamite or guncotton mines. Substituting the values of R thus deduced in $L = MR^3$ we have .6 R = 28.5′; R = 47.5′; $L = \frac{47.5^3}{48.6} = 2204$ lbs. and

$$L = .5\ R = 28.5'; \ R = 57; \ L = \left[\frac{57}{5.43}\right]^3 = 1157 \text{ lbs.}$$

The lateral effect of these charges can be found from S = (d—e) tan α:—if we put $e = 9.84'$, we have S = (28.5—9.84) tan α = 18.66 × tan 53° = 2.49′, for gunpowder mines, and S = (28.5′—9.84′) tan 60° = 32.5′, for dynamite mines.

In order to ascertain how many observation mines will be necessary to defend a channel, we must first find the area of destructive effect of a single mine at the surface of the water; this is found by increasing the above lateral effect by one half a ship's beam (measured at the depth e below the water line), and this may be taken as the radius of the circle of destructive effect.

The size of charges, the kind of explosive, and mutual distances of mines and lines of mines in any defensive system, will depend very much on local circumstances, such as the depth and width of the channel, and the rôle mines are expected to play. Large charges of dynamite require more space for the indirect effects than smaller charges, and two mines with small charges are often more convenient than one large mine. For example, two charges of 660 lbs. of gunpowder each, at the maximum depth and 52′ apart will command a channel of a width of 105′ with an allowance of 40′ for a ship's beam, if both are exploded simultaneously; which is equal to that obtained from 1160 lbs. of dynamite, or guncotton in a single mine.

The Indirect Effect.

The experiments with the pressure cases and pressure gauges were not so regular in the resultant indications as to enable the Board to give any positively accurate expression for the law of the indirect effects. The Board considered Moisson's theory in the light of these experiments in order to approximate a general law.

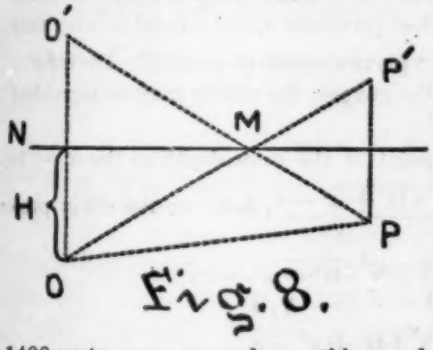


Fig. 8.

In this figure, N N = the water line, O = the centre of a charge at a depth = H, and P = a distant point in the water.

Now a wave of condensation starts from O at the instant of explosion and spreads in all directions with the velocity of sound, 1400 metres per second; as this reaches the surface, waves of rarefaction will proceed from the several points of the surface and spread through the mass with the same velocity, and the instant the point P receives both waves the effect will be nullified at that point.

Now the shortest path to P after reaching the surface will be O M P = O′ P, and the first wave of rarefaction will reach P in the time $t = \frac{O'P}{V}$; the first wave of condensation reaches P in $t' = \frac{OP}{V}$; therefore the effect is operative during $t - t' = \frac{O'P - OP.}{V}$

We may consider the work developed in each instant during an explosion as constant, and that the relative value of $t-t'$ for the different points indicates a ratio between those points and the work developed. If $t-t'$ is greater than or equal to the entire duration of the explosive action, θ, the point P will receive the entire effect. If $t-t'$ is less than θ, P will only receive a portion of the effects, and at all points where the difference between O' P and O P is equal there will be an equal effect produced. A projection of these would be a hyperbola whose foci are O and O', N N is the axis of x and O O' the axis of y. If we put $(t-t') = K$, the equation for the hyperbola gives $\frac{y^2}{K^2} - \frac{x^2}{4\,H^2\,K^2} = \frac{1}{4}$;

but $K = O'P - OP$. $\overline{O'P}^2 = (H+Y)+x^2$ and $\overline{OP}^2 = (H-y)+x^2$

$$\therefore K = \sqrt{(H+y)^2+x^2} - \sqrt{(H-y)^2+x^2}$$

If $H = y$, the point P will be at the same depth as the mine, and this equation reduces to $K = \sqrt{4\,H^2+x^2} - x$. Now, comparing the results of several experiments when the mines and the pressure gauges were at the same depth, they find a definite relation between their indications and the amount of effect produced at the several points; this divided by $K = \sqrt{4\,H^2+x^2} - x$ gives a constant quotient. Therefore, notwithstanding the defects of the gauges, the effects may be regarded as constant during the time θ.

If $b =$ the time in which a point at the same depth as the mine is affected, then as before $b = \frac{\sqrt{4\,H^2+x^2} - x}{V}$, Let $r =$ the effect produced at this point, then $r = \frac{b}{\theta} = \frac{\sqrt{4H^2+x^2} - x}{V.\,\theta}$;

$$\therefore \theta = \frac{\sqrt{4\,H^2+x^2} - x}{V.\,r}$$

From this we can find θ when r, H and x are known; and if θ is known, then solve by $r = \frac{b}{\theta}$, where b is determined for every point by its position relative to the centre of explosion. The lifting force of an explosion is proportional to the charge L, and the upper surface through which it acts upon the surrounding water is proportional to $L^{\frac{2}{3}}$, and we may therefore regard the time in which the force of the explosion is exhausted as proportional to $L^{\frac{1}{3}}$, from which we have $\theta = K\,L^{\frac{1}{3}}$ The constant K has been determined by the most

accurate experiments as K = .0028 for gun cotton, and K = .012 for gunpowder, when the weight of the charge is in kilogrammes.

Let T = the work in metre-tons upon a square metre, which, for instance, is that which is sufficient to destroy a mine case at a depth of H and distance = x, both in metres; let φ = the force in metre-tons developed by the explosive used, and L = the charge in kilogrammes, then $T = \frac{L\,\varphi}{4 - x^2} \cdot \frac{\sqrt{4H^2+x^2}-x}{1400.\ K.\ L^{\frac{1}{3}}}$ by substitution; making $\frac{\varphi}{1400\ K.\ 4\pi} = U$ and clearing the equation of fractions we obtain

$$Tx^2 = L^{\frac{1}{3}}.\ U.\ (\sqrt{4\ H^2 + x^2} - x) \text{ from which we find}$$

$$x^3 = \frac{4\ H^2.\ L^{\frac{1}{3}}.\ U.}{T\left[\frac{T.x}{L^{\frac{1}{3}}\ U} + 2\right]}$$

Berthelot makes $\varphi = 479$ metre-tons for gun-cotton, which gives U = 8.75. At great distances, the fraction in the denominator of the last equation is so small comparatively that it may be neglected, and then, by substituting the value of U, we have $x^3 = \frac{17.5\ H^2\ L^{\frac{1}{3}}}{T}$ or

$$L = \left(\frac{T}{17.5\ H^2}\right)^{\frac{3}{2}} x^{\frac{9}{2}}$$

If we give H and T constant values, this last equation will become $L = A\ x^{\frac{9}{2}} = A\ x^n$ The exponent of $x^{\frac{9}{2}}$ is too great, and does not accord with experience; probably the time in which the explosion is exhausted is less than $L^{\frac{1}{3}}$, at all events the exponent of x must be between 2 and 3. If equal to 2 we should have an effect produced equal to one, though this is only approximately proved by the French experiments. English experiments give the value of the exponent as 3, and these put it at 2.91.

The Board recommends the equation $L = A\ x^n$ for countermines. In this, L = the required charge, A = a coëfficient depending upon the explosive used, and x = the distance at which definite effects are obtained. The exponent n varies between 2 and 3. If the countermines and lines of defence are very deep, use $L = A\ x^2$; if not very deep, use $L = A\ x^3$. In laying out a defensive system, so that neighboring mines may be unaffected by explosions, use the formula

$L = A\ x^2$; and, on the contrary, if to destroy such a system, the charge of countermines should be $= A\ x^3$.

Countermines should be loaded with the most powerful explosives. The maximum charge depends on the means employed for planting them, and the store of explosives brought to the scene of action. In this connection the Board does not consider that charges exceeding 550 lbs. will be used, because of the proportionately large increase in the charge necessary for a small increase in destructive range, and the difficulty in handling large mines when exposed to an enemy's artillery fire. Countermines should be generally used at the undercharged depth, and so remote from the bottom that its irregularities may not interfere with the regularity of the propagated shocks. The Board recommends the depth of from 0.7R to R.

Materials, Construction and Application of Mines.

Cast iron should not be used, because it has not sufficient resistance against countermines without too great weight. The material of the cases must not be too tough, since the case will only be ruptured and not burst.

The Board recommends Bessemer steel plate as the very best material, since it offers great resistance to countermines and is burst into many pieces by the explosion of its own charge, provided the joints are as strong as the plate. Rivets, eyebolts, rings and all projections should be of the best Swedish iron. The thickness depends on the resistance required and the weight that may be permitted. Gunpowder gives its best effects in cases of the minimum thickness depending on the size of the charge, such as 1-16 in. thick for 112.2 lbs. of gunpowder. Air spaces are condemned, and when necessary to give buoyancy should be as small as possible.

Large mines should have proportionally thicker plates; but since the arch or sphere offers the greatest resistance certain shapes may have thinner plates.

The Board recommends the 3-16 inch steel plate case and the ¼ in. steel plates case described in the fifth and sixth countermine experiments as suitable for contact and observation mines.

The same material and similar shapes for ground mines with a suitable base for the requisite stability are recommended; ¼ inch steel plate is suitable for a ground mine containing 1320 lbs. of explosive. Buoyant cases should have an internal charge case of 1-32 inch to 1-16 inch tinned steel. Ground mines should also have an internal charge chamber to separate the charge from the outer case.

Offensive Torpedoes.

The charge for a spar torpedo should be 110 lbs. of gunpowder, immersed 9.84′, and distant 26′ from the supporting vessel. The boat spar torpedo should have a charge of dynamite or gun-cotton of about 33 lbs., and not less than 22 lbs. The largest charge may be exploded from wooden torpedo boats with an immersion of 9′.1 and 1.4 R = 24′ from the stem of the boat or 22.2′ horizontally distant. The smallest charge may be safely exploded when 19.3′ horizontally distant with the same immersion. With iron torpedo boats it is advisable to increase the distance from the mine to 1.5 R=25.5′.

The Harvey torpedo can breach an iron bottom under very favorable circumstances, but there is very little probability that it can be made to strike fair or below the armor, so that it will very rarely be effective even when loaded with dynamite.

The French towing torpedo is superior, since it can be regulated to strike below the armor. Its charge should not be less than 44 lbs. of dynamite, because it may not always be in absolute contact when exploded. It is advisable to hollow out the cylindrical float and pack it with from 220 lbs. to 440 lbs. of gun-cotton when attacking heavily armored ships as this will seriously damage armor up to 12″ thick, even if it should not breach it.

The Whitehead torpedo should be directed to explode below the armor and should have at least 33 lbs. of dynamite in its conical charge chamber.

The report and journal of these experiments are signed by the board of officers representing the three countries; namely, C. H. Arendrup, Captain Danish Engineers; C. Ekermann, Captain Swedish Navy; Johan Koren, Captain Norwegian Navy.

[There is but one point of disagreement between these and our own experiments, and that is in the relative force of gunpowder and dynamite. In these experiments it is considered as 1 : 3 or 4, while it is stated in Professor Hill's *Notes on Explosives*, that dynamite is approximately 6 times as powerful as gunpowder.]

I am indebted to Captain Thomas O. Selfridge in charge of the U. S. Torpedo station for permission to make this extract from my translation and also to Lieut. G. W. Tyler for reading the paper before the Institute.

THE CHAIRMAN: I think you will all agree with me in the opinion that the paper we have just heard read is an exceedingly valuable and interesting one not only to the service at large, but especially to those who have made any study of torpedoes and submarine mines.

The report embraces a large and extended course of practical experiments, methodically arranged, and carefully executed, and the results obtained seem to me to be more complete and satisfactory than have been developed by any previous investigations in this important branch of our professional knowledge.

Whether the ratio of effective explosive force, for different bodies, or the coëfficient of explosion, has been definitely determined may perhaps be a matter for further discussion and experiment.

The conditions of explosion exercise so great an influence upon all explosions and especially upon gun-powder, which is usually taken as a standard or unit of comparison with the more violent explosive compounds, that a perfect agreement in this respect is at present hardly to be expected.

This report appears to be very carefully and thoroughly translated and I think the Institute is much indebted to Lt. Beehler, for placing within reach a paper containing so much practical and useful information, as well as patient research, in connection with a subject which has so direct and vital a bearing upon the conditions of both offensive and defensive modern naval warfare.

NAVAL INSTITUTE ANNAPOLIS, MD.,

APRIL 26, 1881.

COMDR. F. V. MCNAIR, U. S. N., in the chair.

DISCUSSION ON THE PRIZE ESSAY OF 1880.

"THE NAVAL POLICY OF THE UNITED STATES."

Commo. SIMPSON: I wish to bear my testimony to the excellence of the paper of Lieut. Belknap on what should be our naval policy. I have read the essay with interest, and I recognize very deliberate thought and conservative conclusions. Though I don't approve of all his suggestions, yet I find nothing proposed that is revolutionary or unreasonable. I congratulate the writer on the arrangement of his matter, concluding as he does with a summary of the points on which he has dwelt, thus enabling us to grasp certainly at his meaning.

The treatment of the question as to the necessity for the maintenance of a strong Navy by the United States is admirable, and his reasons are unanswerable, supported as they are by numerous instances, in which it is a matter of history that the influence of the show of naval force vindicated our national dignity, and has proved most efficient in general police. The argument drawn from the present state of affairs about the isthmus of Panama is most apt, for we are likely to see the principle of non-intervention in the affairs of the continent violated unless our government has a suitable force with which to support its protest. In case of a war also, we all can recognize that within ten days after the declaration New York city can be put under a contribution for millions to defray the expenses of an enemy, who happens to be possessed of a few powerful iron-clad vessels.

In the third division of the paper we get at the gist of the matter, in the presentation of the means that the writer would propose in order to revive the Navy, and he very sensibly advances the idea of a Naval Board at the Navy Department to perform the duties of the old Board of Navy Commissioners, although the duties at this time would not be so arduous as formerly, as the Bureaus might be retained to aid the Board. There would thus be a professional and responsible body of advisers for the Secretary of the Navy who, in repeating their advice and recommendations, could speak with no uncertain sound, and could thus remove what Lieut. Belknap alludes to as an insurmountable obstacle at the present time, the difficulty of making an impression on the minds of our legislators that the Navy De-

partment has a system on which it will work consistently; for without being satisfied on this point it is right for them to withhold appropriations which they think are only to be frittered away on vague experiments.

The details of the duty for the Advisory Board seem well indicated, but in practice these would naturally suggest themselves, but I note one point made by the writer which I heartily approve; it is the one that refers to special legislation by Congress in regard to individuals, requiring that no such bills shall be considered by Congress except upon the favorable recommendation of the Advisory Board. Of course this would require in the first place an act of Congress, but I believe it is one that would be readily passed if recommended by the Secretary, as it would relieve Congressmen from a serious source of annoyance.

There is one advantage connected with the Advisory Board that has escaped the notice of Lieut. Belknap, which I will allude to. There is nothing that can be done which will approach nearer to taking the Navy out of politics, and as long as it remains at the mercy of politics, so called, but rather at the mercy of party men, all the recommendations in the world will be of no avail. With the Secretary alone at the Department, making recommendations on his personal responsibility, I don't care how much interested he may be in the Navy, he is still the slave of his party, and he dare not, for his party's sake, recommend appropriations for such expenditures as will expose his party to the charge of squandering the public money. But with a Board behind him, having no interest whatever in politics, not removable by party, he will be freed from the trammels of party, and can fearlessly recommend what he honestly believes will be for the good of the Navy, and for the credit of the country; this, I think, is the most important feature that would arise out of the formation of an Advisory Board.

I do not agree with the writer of the essay in the change that he would make in the system of promotions. I think that we have the best system in the world. When extraordinary instances of skill or gallantry occur Congress will always reserve to itself the right to treat them on their merits, meanwhile there is no system so uniformly just as promotion by seniority. During the late administration of the Navy Department the Navy received a shock which alarmed it and which should have the effect of closing more than ever the door to personal favoritism and political pressure.

I disagree with the proposition to dispense with Boatswains, Carpenters, and Sailmakers. The last two can be dispensed with in small vessels, but there are times when their services are all invaluable, and, besides, these positions offer high incentives to the boys that we are trying to train up for seamen in the Navy, and the goal of their aspirations should not be taken away from them.

I agree with Lieut. Belknap in his opinion as to reducing the number of our Navy Yards, as by concentrating the same effort as now we can get better results. I agree with him as to retaining Norfork, Pensacola, and Mare Island, and I would also retain a small station at Portsmouth, New Hampshire, but I would gradually abandon Boston, New York, and

League Island, and I would recommend the establishment on the Thames River, at New London, of what should be the large naval arsenal of the country, removing to it the machinery and tools now at New York, Boston, and League Island, and adding thereto such additional improvements as would be required for a first class yard fit for a nation of fifty millions of people. It would be out of place for me to dwell on this matter, but I agree with Lt. Belknap that at present our expenditures for navy yards are spread out over too much surface.

Lieut. R. P. RODGERS: The plan of the system of promotion proposed by Lt. Belknap seems to me one of the most striking points of his Naval Policy which I have read with much interest. Although it has many features which should recommend it yet I doubt whether it would be acceptably received by the service at large. It is practically the French system, by which an officer is sure to get his promotion by seniority, and may secure it earlier by distinguished merit or by some signal act of service. Whether such a system, generally applied, in our country, would not be abused by means of political influence and patronage is a question to be solved only by experience.

I would, however, advise a plan of a similar but less extensive nature. I would recommend the plan of *selecting* our *flag-officers* from the list of captains. No captain should be eligible for promotion until he had seen a stated term (say two or three years) of sea service as a captain. By this means the best captains would seek commands as soon as they entered the grade, and with the incentive of a possible promotion before them, they would put forth their best exertions to improve their ships, (and thus the service) in every possible manner, in other words they would naturally take greater pride and interest in their work.

The flag-officers *selected* might not always be the best men eligible, but they could certainly be men of some distinction. Promotions to brigadier generals in our army are made in this manner and as yet no man without merit has been advanced. It would probably prove equally good if adopted for the Navy.

If this were done, flag officers would all be men of high intelligence, broad views, and strong character. The head of the Navy would then be strong, and the body would soon feel the influence of its strength.

I believe that this would prove a beneficial change in the system of promotion of our Navy, and I think it is probably the only safe one.

It may be claimed that the commanding officers also should be selected, but by increasing the field for selection there would be more scope for political and other outside influence: and although I think such selection would undoubtedly be beneficial (should it be judiciously made) yet the innovation would be so decided that I do not believe it would be accepted by the service.

P. A. Engnr KAFER: The first and as far as I can see the only step in the future Naval Policy of the United States as set forth in the essay is to re-establish a Board of Navy Commissioners which shall be an Advisory Board to the Secretary of the Navy.

If this Board is to direct the Secretary what to do, or order the Bureaus to do whatever it appears to the Board most expedient to be done making their decision final in all matters connected with the Navy Department then the office of Secretary of the Navy might be abolished as he would be a figure head only; but if the Board is to be under the direction and supervision of the Secretary, being advisory in its action, and only that, I can see no necessity for creating such a Board, giving the Secretary three advisers in addition to the eight provided by law; the Secretary can now get the opinion of any officer from the highest to the lowest if he desires it.

The reason for organizing the Bureau system in the Navy Department, was to fix the responsibility of any act performed under the cognizance of a Bureau, which was found to be impossible under the workings of the Board of Navy Commissioners prior to 1842.

Congress and the Secretary of the Navy were in accord on this point and both deemed it necessary to the interests of the Navy to abolish the Board of Commissioners and substitute the present system, not because there was any objection to the members of the board; as they were appointed as chiefs of bureau by Secretary Upshur, immediately on the bill re-organizing the Navy Department becoming a law; the objection was to the system.

Secretary Upshur in a communication to Congress stated that though the reorganization of the Navy Department under the system recommended would involve an increased expenditure of $19,000 per annum to pay the salaries of these bureau officers, it would, by fixing the responsibilities of such bureau and every act performed under its cognizance, be a saving of $700,000 to $800,000; and not only was the Secretary anxious for a change, but Congress also demanded a change in the administration of affairs in the Navy Department.

And now it is proposed after an experience of nearly forty years with the bureau system to go back to a system that was unsuitable to the wants and requirements of the Navy, when they were much simpler than they are to-day.

The author of the essay says that, "there was no call for the abolition of the Board," but from the records of the debates in congress and the communications of the Secretary of the Navy at that time, it will be seen that there was a decided call for the abolition of that Board, and the wisdom of the change was not questioned at that time.

Will we get officers as members of this proposed Board that are in any way superior to those selected as chiefs of bureaus? I think not.

The supposition is that we get the best man for chief of bureau, and we would take this same man as a member of this proposed Board, and the next best man for chief of bureau.

In reference to the question of the establishment of such a board as proposed in the essay, I will quote from a letter of a Chief of Bureau on this subject.

"I can conceive of no possible object in this. The present bureaus constitute an admiralty board with all its advantages and without its defects. The only modification I would suggest would be to require, by

law, a daily meeting for conference presided over by the Secretary of the Navy or senior Chief of Bureau present, the minutes of the proceedings to be taken down for future reference.

If a separate admiralty board was constituted and the bureaus retained it is probable that the same reasons that created me Chief of Bureau would put me on that board, and some inferior man put in as Chief of * * * ; and so with all the other chiefs, which would do nothing to conduce to harmony of action.

The reunion of chiefs proposed with their language taken down would prevent its assuming the character of a debating club, and each man become responsible for the advice he gave the Secretary; his views, if erroneous, being combated on the spot by the other chiefs."

The late Commodore F. A. Parker says, when writing on this subject:—"Much has been said of our defective system of naval administration; but when we remember that under that system a force was organized in 1861 that effectually blockaded our sea-coast from Virginia to Texas, a Herculean task which Europe pronounced impossible; and a number of monitors put afloat in 1862, which excited the admiration of the world; and further when we recall the triumph of American over English ideas in the memorable conflict off Cherbourg, of June 19, 1864, I do not think we need cross the ocean for instruction."

And with the opinions—as here expressed—of these eminent officers of the Navy I fully agree.

The Naval Policy of the United States has been much discussed by officers of the Navy, and these discussions have left the impression on my mind that the naval policy as well as the policy of the naval officer, is to induce Congress to appropriate money enough to build ships that will compare favorably with those of England and France in numbers as well as in kind;—but the naval policy as set forth in the essay is, the re-establishment of a Board which was acknowledged on all sides to be a failure forty years ago; and if this is to be the future policy of the Navy, I think we are much better off without a policy.

It has been said that Congress would furnish the money to build ships if the Navy Department would furnish the designs for them.

On the contrary I believe that there are designs for vessels with all the details of construction now ready and only awaiting an appropriation from Congress to build the ships.

The monitors now on the stocks should be completed, and would make very efficient war vessels of their class;—though by no means such vessels as might be designed to-day.

As the author of the essay, says "after all it is Congress that decides the Naval Policy of the country."

If Congress should agree with the author of the essay, and authorize a Board, organized as proposed, the members being specialists in their own profession; that of ordnance, seamanship and navigation,—these subjects they would be fully competent to judge, and their opinion on them would be of more weight than the opinion of any one who had not made these

subjects a study and followed them as a profession; but in fixing on the best type of ship or to get a ship that will fulfil the conditions required of her, as to speed, ability to maintain that speed for a given time, strength and weight of the structure, stability and many other details, a special knowledge of the profession of engineering, and naval architecture, practical and theoretical, is necessary.

The engineer and naval architect are better fitted, than a navigator, seaman or ordnance officer, by their special professions, to form an intelligent opinion on the subjects of engineering and naval architecture.

The bureaus, that must work in accord to make a successful vessel of war, are Ordnance, Engineering and Construction, and as I have already said, must be men competent to judge of all the details of a ship; and these men we now have as the chiefs of bureau.

If specialists are not best fitted to judge of subjects pertaining to their own profession; then if a question of ordnance is to be considered, the Board should be composed of persons having no special knowledge of ordnance, instead of officers that make that subject a professional study, and if the subject to be considered is chemistry, the Board should be composed of persons who are not chemists.

But it is well known that when any person or organization wish an opinion on any subject, they seek that opinion of those who have made that subject a study, and for this reason I consider that such a Board should be composed of all the chiefs of bureaus instead of three men who may be very eminent in their own profession, and fully competent to judge of any question pertaining thereto, but not as competent to give an opinion on matters pertaining to other professions.

It has been asked what ships have we now, that have been built under the bureau system. I point to the Trenton, ships of the Vandalia and Adams class built since 1870; the Vandalia class have equal if not greater speed than the vessels of the Gem class of the English Navy, vessels of about the same size as the Vandalia; the frames of the Gem class, being of iron, they are superior in that respect; the height of the boilers of the Vandalia class being about two feet less than those of the Gem class and with the same draught of water, places the boilers of our own vessels, two feet more below the water line, giving them greater security and protection from shot.

These vessels, I consider good vessels of their class, and a very desirable class. Much has been said of the worthlessness of the vessels built between 1861 and '65; but they were good vessels; they served their purpose, fulfilling all the demands required of them; it is true that they are rotten, but it was known at the time they were built that they would not last, they were built chiefly of white oak, the best timber that we had; but had the frames been made of iron,—as they might have been—instead of wood, we would have a number of good cruising ships to-day.

It was due to the conservative influence in the Navy that they were built entirely of wood; but since then we have made some progress and I hope to see still more in the right direction, instead of going back to the ways of forty years ago.

Comdr. COOKE: I have read with great interest Lieut. Belknap's prize essay on the Naval Policy of the United States. He has certainly drawn a very truthful yet unflattering picture of the condition of our Navy. Indeed were its efficiency at the moment alone to be considered, it might with accuracy be ranked after that of Holland, and perhaps after those of Brazil and Japan.

We have not a single armored sea-going ship, and can hardly be said to have any modern cruising vessels, and no armaments of modern rifled guns; yet a brief glance at the very complete and excellent annual reports from the Navy Department is sufficient to set forth how earnestly the naval authorities have begged and implored Congress, from year to year to provide the necessary funds for keeping abreast with the times.

Besides being the right arm of our national defense, our navy is, of course, an important and necessary ally of our commerce, and their development must be mutual. The point to which its efficiency should be carried must, therefore, depend, in a great measure, upon the amount of commerce we have to protect.

Our Navy may be sufficient now to protect our commerce, in the present stage of its development, for we can hardly be said to have either Navy or commerce worthy of consideration. But as our surplus productions are annually increasing and must be transported to foreign markets or become a total loss in our own hands, the question whether or not the Navy shall be improved so as to provide for this state of anticipated development must quickly be decided. And it is well to remember, that if the freights paid by our people to vessels sailing under foreign flags had been retained at home and allowed to become part of our national wealth, our ability to meet and overcome the embarrassments of trade would have been greatly increased. It is very clear that we cannot afford to continue our dependence upon foreign nations for the transportation of our surplus products to the markets of the world. The benefits and profits of our own carrying trade belong to our own people and should be enjoyed by them.

We are certainly the great "middle kingdom" and have the most favorably located business stand on the face of the globe. From our geographical position and territorial advantages we may justly aspire to commercial supremacy, which if we fail to achieve we cannot expect to maintain a position in the front rank of nations.

From the whole of our vast country comes one universal wish for a restored American marine. We are great in production, great in internal commerce, and the whole country is now looking with anxious hopes for the building up of our shipping interest and of making it our principal arm of defense in war and our proudest boast in peace. Why should we not hope for a glorious future for our marine if we will only devote our enterprise and intelligence to this important interest, so long prosperous in the past.

Under our present policy and laws we cannot successfully compete with foreign countries in our ocean carrying trade, and the remedy must be to relieve our shipping employed in foreign trade, from all restrictions and

burdens which place it at a disadvantage in competing with foreign vessels. This must be accomplished in the near future, and all admit that our marine resources must be restored or we shall be disarmed of our defence, and our productions will be at the mercy of the nation which possesses itself of the means of carrying them. Should we not, then, at once begin to remove abuses, to introduce improvements, and to build up our long neglected marine?

We have stood with folded hands and permitted our rivals in naval power to get far in advance in a line of improvements in which the United States not many years ago knew no superior.

The first step in the future naval policy of this country, as recommended in the essay before us, might be taken at once, by order of the Secretary of the Navy, and would be a great stride in the right direction. It being the establishment of a Board of Naval officers, which should determine certain vital points, therein briefly summarized.

The recommendation to modify the present system of promotion by seniority, by occasional selection, would not accomplish the desired result, as those most influential and not those most deserving would gain by it. To encourage retirement would be far better.

It is useless to attempt to enlarge upon the points suggested in the prize essay under consideration, but I am sure you will agree with me that it is full of excellent ideas which we should earnestly advocate in the hope that our naval policy may be fixed and its development commence at the earliest possible moment.

Lieut. BELKNAP. If the appointments to the position of warrant officer could be made solely upon the recommendation of naval officers through the Advisory Board, the grades would doubtless be useful as incentives to the naval apprentices, as suggested by Commo. Simpson. But would not the end be as effectually gained by making the chief petty officers permanent positions dependent upon good behavior, and would it not be an incentive equally stimulating to the apprentice to know that by length of service, good conduct and ability, he would inevitably fall heir to one of these ratings independently of the political influence his friends might have? With the exception of gunner, the usefulness of these grades passed away with the sailing frigates, and I trust Commo. Simpson will pardon me for saying that I see no reason why we should continue to swell the total number of officers in the service by some one hundred and seventy-five (active and retired) and to deprive our already too crowded berth decks of the space that might be gained, for the sake of affording an incentive to the naval apprentice.

The plan for the promotion of flag officers as suggested by Lieut. Rodgers is rather more of a sweeping change from the system now followed than mine, for it would certainly be a greater innovation to choose all of the flag officers by selection instead of every third one, and with how much more force would the objection on the score of political influence apply in the former case than in the latter. But with an Advisory Board to choose the officers to be promoted why stop the selection at flag officers? As Commo.

Simpson so ably says, nothing could be done which would approach nearer to taking the Navy out of politics than the establishment of an Advisory Board, and that being the case we might feel confident that the recommendations of the fitness of an officer for promotion over the heads of his seniors in length of service would be free from political influence or party bias. Congress has the power to advance an officer a grade, but only for war services, or for extraordinary heroism; my plan provides for peace, to prevent minds rusting during the long years that must elapse before promotion. Take for instance the graduates from this School. We all know that each year some manage to get through by hook or crook who should not. Should not the bright men of the succeeding class be given an incentive to perfect themselves in their profession and what more fitting one than that they should step over the heads of the laggards in the class above?

To Congress it is that we look for our very existence; it is to Congress then that we should naturally look for a naval policy. But without a policy we can so prepare ourselves that when one is adopted we shall be ready to take advantage of it. This can best be done, in my opinion, by the establishment of an Advisory Board. The needs of the service will then be defined, and the unification of its management being completed, steps can be taken to place the Navy in a condition worthy of a nation of fifty millions of inhabitants.

Undoubtedly the Secretary of the Navy can get opinions from the different chiefs of bureaus, but do they agree? Is it not necessary for the Secretary after they are received to endeavor to form the diverging, and, but too likely, directly opposite opinions into a settled plan? That this can be done and that a master mind can wrest success from such unpromising sources is evident from the management of the Navy Department during the late war. But similar circumstances would have to recur to permit any one man taking the responsibility and sole direction of affairs as Mr. Welles did. In time of peace few men not trained in the service would venture to act on the plan of one specialist as opposed to that of another, both being chiefs of bureaus.

But with a wise and competent Advisory Board to advise and encourage, as Commo. Simpson shows, the Secretary would be able to guide with no uncertain hand the branch of public service committed to his charge. The growing wants of the Navy in 1842 demanded the establishment of the Bureaus, for it was too much to expect that three men could give the care to the details for which seven are now necessary. But in the itching for change the Advisory Board fell. I think, and I am not alone in this opinion, that it would have been far wiser to have increased its efficiency by establishing the bureaus, subordinate to an extent, but charged with special duties, leaving general affairs to the Board. In proof I say look at the state of affairs to-day:—seven heads, often working against one another, often with entirely different plans for ships—interior arrangements, discipline, et cet. The responsibility of some things may be fixed, but who is responsible that we have no Navy worthy our nation? Is it not on account of the lack of unity shown? Does it not to a great extent arise

from the desire of each Bureau to be left alone and to claim non-interference on the score of non-interference?

The fault was not in the old system; that worked admirably. The three commissioners needed executors to carry out the details after a general plan had been decided upon. We cannot say that better men can be found for the Advisory Board than we have for chiefs of bureaus. Were not the same men who were commissioners made chiefs of bureaus? The Advisory Board would not build the ships, nor put the engines in, nor yet the guns: but after deciding upon the class or type of ship required to carry the gun selected, it would say to the constructor, build the ship; to the engineer, design and construct the engines. The men who go to sea in ships, who command them and who have to fight them, might then have some regard paid to their ideas. As it is the constructors build and say to the engineers and ordnance officers, put in your engine and guns as best you may.

I have listened with great interest to the criticisms passed this evening upon my essay and while it is but natural that differences of opinion should exist as to the remedy, I think that all who have spoken can hardly but recognize the fact that we have no naval policy, that we go on year after year in a hap-hazard way trusting to luck, and that it is only when a strong and prevailing sentiment exists that any decided step is taken. I believe further that most of us must feel that the future is unsettled, not to say dark; that the Navy may at any moment after a futile resistance be swept from existence on the seas. And I ask you, is it not time that we, representing different branches of that Navy, should, sinking minor differences, join together to bring about a change that in case of our Country's need would give us an opportunity of supporting its cause with some show of success? Can we afford to go on, with no settled plan, with conflicting aims, until war opens our eyes to the necessity of our unification? I believe that men can be found among us, who, appointed to the Advisory Board, could be just to all, partial to none. They need not be specialists who are generally men of bias, but they should be men of sound judgment, clear views, and impartial minds. I have sufficient trust in human nature to believe that such men can be chosen, and their voice, speaking for the Navy, would lift us from the slough into which we have fallen and restore us to the position we should occupy among the navies of the world.

NAVAL INSTITUTE, ANNAPOLIS, MD.,

JUNE 8, 1881.

REAR-ADMIRAL C. R. P. RODGERS, U. S. N., in the Chair.

A PROPOSED ARMAMENT FOR THE NAVY.

BY COMMO. E. SIMPSON, U. S. N.

My object in addressing the Institute is to ask its attention to the consideration of the important subject of the ordnance of the Navy, and to suggest some ideas which may assist to lead to general agreement upon this great "want of the Navy." We all agree on one point in reference to this matter, which is that we are deficient, that we are behind the times, and that it is absolutely indispensable that we must make a determined and vigorous effort before we can hope to resume our old position among the nations of the world, but while we agree on this point, and while each is ready to suggest some remedy, we have concluded upon no fixed line of action, and our confused and sometimes contradictory suggestions can have no effect on the government in inducing a supply of the necessary means to accomplish our purpose, for Congress naturally hesitates to appropriate money for a purpose on which it sees that the experts on whose judgment it must rely for guidance in legislation, are themselves divided in opinion. My object, then, is to submit to this body of experts the result of my matured reflections on this subject, giving my reasons for the faith that is in me.

Before proceeding to legislate for the present and the future it is the course of true wisdom to review the past, and to gather from such retrospection such rules for guidance on the general subject as may be useful in directing us aright, for there are certain fundamental principles involved in this matter which must not be discarded nor be allowed to lose their controlling influence in the excitement caused by embarking in new ideas; the furor attending the embracing of a novelty

must not make us desert first principles,—this is true wisdom. There is no doubt that in the past the Navy of the United States has been most happy and successful in the possession of ordnance of especial excellence. There is no department of our public service that has been more fortunate in the selections that have been made of officers to direct it than that of our naval ordnance; the names of Warrington, Morris, Harwood, Ingraham, and others, show to us the care that has been taken in the selection of men who were fitted for the work, and the name of Dahlgren is known not only to us but to the world as that of the founder of a system which in its time was the type of perfection and the standard of imitation. In the period of change through which artillery has been passing during later years the names of Case and Jeffers are known as suitable successors to the before-mentioned, the latter having brought to the Bureau the results of many years of practical experience and study, and having proved himself, during a very trying time for the reputation of an artillerist, well worthy of the responsible position in which he has been placed. That Commodore Jeffers has not gone farther than he has in the road of development may be due to circumstances not under his control, and we have a right to conclude from his official statements that he is not content with the present condition of our ordnance. In thus bearing testimony in commendation of what has been done, without giving it my unqualified approval, you will recognize that, in any suggestions that I may submit, it is not my intention to animadvert upon the results that we now see nor to criticise harshly the acts of others; I shall but express opinions which I think if adopted will expedite the result that all so earnestly desire. With this preamble, simply to show the spirit in which I approach this subject, I will now proceed to its consideration.

As I remarked before, we must begin at first principles, and we must understand what was the chief cause of our former superiority over the other nations of the world in this matter of ordnance. It could not be a matter of accident, such men as we have mentioned did not trust to luck, nor determine a calibre nor the dimensions of a gun at hap-hazard. We must see what law controlled them in their designs, and we must see whether, under the new conditions of the subject, we must be bound by it, or whether we are at liberty to depart from it.

With the smooth bored gun, the greater the calibre, the greater was the range, accuracy, and penetration. The well known laws that govern spherical bodies opposed by the resistance experienced in passing through air are well known to you, and exhaustive experiments proved

the proportionate penetration in wood due to calibre. Up to the calibre of XI inches the increased weight of the smooth bored gun was not felt as an inconvenience, for the increased charge of powder and weight of shot added so much to the moment of recoil that the additional weight of the gun assisted to control it. The question is now whether, under the new conditions, it is necessary, in order to secure range, accuracy, and penetration, to adhere to the old rule and to aim at large calibres.

Now I do not propose to deny that even with rifled cannon, the larger the calibre, other things being proportionately increased, we will secure increased range and effect; of accuracy, we may safely assert that it will not be increased by increase of calibre. We ask then if the increased range due to increase of calibre is wanted when, with the smaller calibre, we can obtain all the range that we can possibly avail of within distances really practicable for sea fighting, and we must allow that the range of any rifled cannon of ordinary calibre is all sufficient for all practical purposes. For accuracy and range then we can conclude that in order to secure these qualities we do not require large calibres for rifled cannon. As to penetration and effect I will postpone my direct remarks on the point, leaving my position on it to evolve from the following treatment of the subject.

In considering myself relieved from the trammels of calibre, I take it for granted that I will not be misunderstood as disallowing any of its advantages. I only wish to assert that, under the new circumstances of rifled cannon and elongated projectiles, the conditions are so altered from what they were with smooth bored cannon and spherical projectiles that sufficient energy of shot may be obtained for all practical purposes from guns of moderate calibre, and that by adopting a battery of easy manipulation we may be saved from the necessity of imposing upon guns' crews the labor of handling ordnance material of great weight.

The very important consideration, also, of the character of vessels that we are called upon to arm bears directly on this point. Judging from what we can gather of the majority opinion of the Navy, and of the disposition of Congress, our Navy is to be limited to unarmored cruisers. I mean our cruising, sea-going Navy. Iron-clad monitors, from present appearances, seem destined to embody all of armored vessels that we are to possess, and they are only fitted for harbor defense and for service along the coast in the vicinity of harbors. It is the unarmored cruiser that we are now keeping in mind when planning a system of ordnance for the Navy.

At the outset of this investigation there is one thing that ought to present itself to our minds derived from our own practical experience on board ship, and that is the necessity of avoiding a multiplicity of calibres. There was a time when a practical uniformity in this respect was achieved in the armament of our ships of war, but since the partial introduction of rifled cannon we have wandered sadly away from the lesson that we had so well learned. This has been caused by the process of change being so very gradual, and the tentative style of the introduction of each experimental gun, but if the change from smooth bored to rifled cannon is determined on it ought to be done at once, and there will be the opportunity to re-establish this desired uniformity without loading ourselves with a supply of experimental guns which must disappear from the batteries, and become useless stores, when we adopt a permanent armament. The presence of these mixed batteries makes the practical work of manipulating them very complicated, and makes the process of serving the ammunition an intricate question to solve, as each calibre requires a distinct and separate detail of men to be appointed for its supply. In addition to the smooth bored guns which, as yet, form the chief part of our armaments, almost every ship carries an 8 in. rifle, a 6 in. rifle, and other smaller rifled cannon in battery which have to be supplied with ammunition in action; these, in addition to a small steel rifle which ornaments the poops of our ships of war, and boat guns, and machine guns. This shows the unsettled condition in which this matter rests. Our batteries are all experimental, no conclusion seems to have been arrived at as to what is best to adopt, and the present multiplicity of calibres is the result. In planning an armament for the Navy it is necessary to keep in view this important requirement, and to adopt a calibre well fitted for *general* instead of *special* purposes. There must, no doubt, be some exceptions to this rule, as, in special vessels where machinery is adopted for working the guns, exceptionable calibres will be admissible, but I speak of unarmored cruisers which are to constitute our sea-going Navy, and in which the guns are to be served by man power.

It will be well to mention here a particular phase of the present development of artillery, which, to my mind, forces the suppression of all of these small guns that help to make up the mixed batteries of our ships of war, for in view of the development I refer to I can see no practical use to which they can be put. The 6 in. rifle on the top-gallant forecastle, the small steel rifle on the poop and other small pieces are all on an uncovered deck, and before they can be of any use against

ar enemy they must be used at close quarters. Now in the advanced condition of machine guns I think it is evident that no guns can be served at close quarters on an uncovered deck. All ships of war are now supplied with the Gatling, or other machine guns, and as soon as contending vessels approach within the range of these pieces the uncovered deck of the adversary will be swept by them. In single decked vessels this exposure cannot be avoided, but in a double decked ship if guns are to be mounted on a spar deck they must be placed so as to be protected by the forecastle and poop decks. In passing, I would say that in order to avoid weight at the extremities of a ship, I would extend the forecastle well aft and the poop deck well forward, in order to afford this protection, but guns so mounted should be of the same calibre as those that form the main battery on the covered deck; and, if "all around" fire is deemed essential, it can be obtained, as in one of the types of iron clads, by introducing the "tumble-in" system of constructing the upper works forward and aft. This arrangement will answer the objection that might be raised to my proposition to suppress the gun on the top gallant forecastle, that by so doing I deprive the ship of her bow chaser; fire ahead will be better provided by this arrangement and the gun will still be serviceable at close quarters. But this is a point rather of construction than of ordnance, but closely associated with it, and affords a good illustration of the intimate connection between the two; I throw out the idea as a practical suggestion and pass on to the consideration of *the* gun which with safety we might adopt for general purposes in the Navy.

It is no new idea to have a *special* gun for the Navy; we have had one for years; the IX inch Dahlgren gun has occupied that place, and we regard it as especially our pride and our defence. It constitutes the main feature in the batteries of all our ships of war, and if we are satisfied that under the new condition of things it is necessary for us to change our batteries, would it not be the path of wisdom to devote our investigations and our experiments to selecting a substitute for the gun which occupies the most useful and important place in our armaments. By selecting a gun to take the place of the one of which we use the greatest number we advance by the shortest route to solve the problem of new armament; consequently, instead of experimenting with guns of which, if we select one, it will only be for use as a pivot gun, of which we use but few, I think it would be wiser to first determine on a gun for broadside batteries, of which we require many.

In opposition to this idea it will not do to say that the whole Navy

is in a state of change, and that, if we at once embark in providing ourselves with a large number of guns for broadside batteries, we may find, after we have them on hand, that the style of our ships may be changed, and so to argue that no decided move should be made in providing full batteries until the character of the ships of our future Navy is determined; this excuse for delay is played out, there is nothing in it, and it has done much harm already in deadening effort and checking invention. The character of our future Navy is determined, at least until the time of the next war in which we may be engaged, for it will not be until then that any iron clad sea-going cruisers will float our flag on the sea, and until then we can feel assured that our cruising Navy will consist only of unarmored cruisers of wood, or composite build, of moderate dimensions, for which our present guns would form adequate armament if it were not necessary to provide rifled ordnance so as to put them on an equal footing with similar vessels of other nations. There is no excuse for delay in this matter in consequence of the seeming undetermined character of the ships which are to carry the new guns, and all we have to do is to find some gun of about the same weight as our present IX inch, only of immensely increased power.

The weight of the IX inch Dahlgren gun is 9,000 lbs., and that of the carriage is 1,300 lbs. In order to approximate to the same total weight, and at the same time to secure a gun of greatly increased power we must expect to increase very much the weight of the carriage, for the increased energy of the shot will impart an increased energy to the recoil which must be provided for by the carriage, and we are thus forced to select a gun which will be of less weight than the one that we wish to replace. In looking over the list of modern guns, which have proved to be an undoubted success, I select the 6 inch steel gun of Mr. J. Vavasseur, which seems to me to offer to us a ready means of emerging from our present embarrassment. I will give some of the particulars of this gun.

Weight 3 tons, 17 cwt.
Length, 162 inches.
Diameter of bore, 6 inches.
Length of bore, 150 inches (25 calibres).
Charge of powder, 40 lbs.
Weight of projectile, 80 lbs.
Muzzle velocity, 2,000 ft. per second.
Total energy, 2,219 foot tons.

Penetration in iron at muzzle, 11 inches,
at 500 yards, 9.9 inches,
at 1,000 yards, 8.7 inches.

You are all familiar with the power of the IX inch gun, so it would be supererogatory for me to dwell on it in comparison with the above; and I avoid doing so from the affection that I have for the old piece. I would not wish to seem to belittle it, but it cannot help being a smooth bored gun of cast iron, and we must, with what sentiment you will, quietly and tenderly store it away with our obsolete bows and arrows, in our museums of war material, where we can take the youthful gunner and show him the weapons with which his ancestors went to war. There was a time when it did good service, it has been heard speaking for the nation in foreign lands, it has borne its honorable share in preserving the Union, but it is unfair now to pit it against the gun of the present.

I propose, then, the Vavasseur 80pdr. as the gun to select for our broadside batteries, and the particulars which I have given demonstrate its ability to discharge all the duty that we could require of a gun in the new conditions of artillery.

The weight of this gun is less than that of the gun it should displace, but the carriage is much heavier than the Marsilly carriage on which our present batteries are now mounted in broadside. Such a gun as the Vavasseur 80pdr. could not possibly be controlled on a carriage alone, it requires a slide besides, as well as all the modern improvements of hydraulic compressors. The carriage which is prepared for this gun has an adjustable automatic compressor which involves much of what you all, no doubt, remember as being the characteristics of the compression used in what has been known as the "Vavasseur gun carriage," united with the hydraulic buffer, which is ingeniously added to the old arrangement. To make myself more distinct—the old Vavasseur compression was produced by revolution of a long screw between the rails of the slide, extending lengthwise, on the forward end of which was fixed an iron cone or disk having metal bearing surfaces sunk into its periphery. This cone or disk worked in a wrought iron drum which had a conical recess bored to suit it similar to a friction clutch. The drum was surrounded by a metal brake strap having a tightening screw with pointer and scale. The grip of this strap on the drum determined the amount of compression, and consequently the velocity of the revolution of the screw, which determined the velocity of the recoil of the gun, for the top car-

riage was connected with the screw by a cast iron nut which clutched the screw, and which was propelled along the screw by the motion, in or out, of the gun and carriage. This was an admirable motion, and the same idea of screw motion is adhered to in the present Vavasseur arrangement of the hydraulic principle, but differently applied.

In his adjustable, automatic, hydraulic compressor Mr. Vavasseur has two cylinders in the use of which the screw principle is introduced by means of rifling the interior. The compressor cylinders rest on the top of the brackets or sides of the carriage of which they form a part; these cylinders are connected together at the rear by a pipe, and are rifled each with two helical grooves. A groove, or score, is turned on the circumference of the piston into which is fitted a gun-metal ring or valve having two projections which fit the grooves of the cylinders. Across each piston and valve are cut two or more openings or passages, making direct communication across the piston from one side to the other.

The piston rods of each cylinder are attached to brackets fixed one at the front and the other at the rear end of the slide. Means are provided by which the piston can be rotated so that the openings in the piston can be placed in any desired position with respect to the openings or passages across the valves; from this it follows that the passages across the pistons can be closed at any desired point.

The piston rods, being attached, one to the front and the other to the rear end of the slide, it is evident that, as the cylinders move during recoil, one piston rod is being withdrawn from one cylinder while the other piston rod is being pushed into the other cylinder, and the liquid displaced by one rod flows through the connecting pipe and exactly compensates for the deficiency caused by the withdrawal of the other rod. This arrangement allows both cylinders and connecting pipe to be kept full of liquid and also entirely suppresses all air spaces. The twist in the grooves is such that while the passages in the piston may be wide open at the commencement they may be nearly, or wholly, closed at the end of the recoil. These passages can be made so large at the commencement of recoil as to reduce very much the strain on the pivot bolt of the slide.

This description gives a general idea of the carriage which is used with the gun that I propose, and one of these carriages is being now used at Woolwich in the experiments that are being made there with the 6 inch R. B. L. Armstrong gun, lately completed on an order from

the English Admiralty. The French Naval Artillery have experimented with this carriage with most successful results with guns of 24 cm. calibre.

It would be impossible to give in more full detail an account of this carriage unless we were provided with detailed drawings, or, better yet, had a specimen carriage under our survey; but enough has been said to show that, great as is the energy of the recoil of the gun that I propose for the main armament of the Navy, a carriage is already provided which is able to restrain and control it within safe limits.

The next point that would naturally have to be considered in deciding on this important question is whether it is practicable to mount such a gun on our ships of war. The question of weight comes first. The 6 inch, 80 pdr. Vavasseur gun weighs 8,624 pounds, the carriage and slide will weigh about 5,000 pounds, making the total weight about 14,000 pounds. In comparison with this we have the weight of the Dahlgren IX in. gun given at 9,000 pounds, and that of its carriage at 1,300 pounds, making 10,300 pounds in total weight. We have an excess of total weight of about 4,000 pounds; is this an objection that merits much consideration? I think not. Let us see what we already have done, in the matter of increasing total weight of battery. Take the armament of the Trenton; she is armed with 8 inch Palliser guns. The "table of elements for various guns" in the Ordnance Instructions gives as the weight of the gun 17,000 pounds, and that of the carriage as 3,790 pounds, and a foot note explains that this is the weight of the top carriage alone; the weight of the slide is probably 4,000 pounds more, which will give us a total weight of this gun, carriage and slide, of 24,790 pounds! This is an excess in total weight over what I propose of nearly 11,000 pounds! If the experiment in the Trenton is only a partial success there can no objection on the score of increased weight, be raised to the change that I propose: and, as the gun is infinitely superior to the Palliser 8 inch, which forms the battery of the Trenton, it could be substituted, with the advantage of increase of power and reduction of weight, for the guns that that ship now carries. This dismisses the enquiry so far as concerns the matter of weight, now as to space, deck room to accommodate the slide.

The length of the slide that is now on trial with the 6 inch R. B. L. Armstrong gun at Woolwich, is 126 inches, or 10′ 6″. Add to this the necessary space between the front of the slide and the spirketting to allow for training, say two feet, and we have a length of 12′ 6″ which

must be accommodated with deck room. We will find, by referring to the deck plans of our ships of war, that we have ample space for a slide of this length on board of all of our 2d rates, except, possibly, in the gangways of the Alaska class, and that nearly all the 3d rates can carry the gun on broadside. The length of slide is admirably fitted for the Quinnebaug class particularly. Here, again, we refer to the slides now in use on board of the Trenton; the slides to which the hydraulic buffer is fitted require a length of 14′ 3″, which, with the space for training, makes necessary a deck space of 16′ 3″. This slide probably could not be accommodated on board of any other 2d rate in the Navy, certainly not by the 3d rates.

We conclude, then, that there is no objection on the score of want of space, and as the builder of the carriages says that he sees his way to reducing the length of the slide still more, we may safely assert that this powerful gun can be mounted on board of all of our ships of war that can deserve the name.

In an early page of this paper I referred to the old binding rule of calibre which had controlled our ordnance under the régime of smooth bores, and in considering the new conditions of things under the régime of rifles, I had dismissed the binding force of calibre so far as range and accuracy were concerned. As the gun that I propose can develop an energy of 2219 foot tons and penetrate 11 inches of armor, I think that I have disposed of any objection that can be urged against reducing calibre on the score of penetration and effect. The fact is that the old expression for energy $\frac{w\,v^2}{2\,g}$ still holds good, we are not deserting our old position; but with the spherical projectile we were limited to a certain velocity, consequently the important factor was the weight which was increased by calibre; but in the present conditions we find that we are not so limited in velocity, and as the energy will increase as the squares of the velocities, while it only increases directly as the weight, it is evident that increasing the velocity immeasurably increases the value of the whole expression, and my position resolves itself into this, that if we can attain a velocity of 2000 feet per second with a 6 inch rifled projectile, weighing 80 pounds, we will have secured a most formidable armament for our Navy. Such a gun can be applied at once to every ship in the service, large and small, and if the larger ones are capable of carrying one or more guns of greater calibre, it would be easy to adopt them, but the great want of the Navy now is a gun for general purposes, to take the place of the IX inch gun on broad-

side, and I know of no gun that more perfectly would supply the demand than this one of which I speak. The gun has passed through all its experimental stages; it is an acknowledged success, and the carriage which is fitted for it has so commended itself to favor that it has overcome all the prejudices of Woolwich, or rather of the English Admiralty, and is now likely to be adopted into the English Navy, for, as I stated, it is now under trial with a 6 inch R. B. L. Armstrong gun made for the Admiralty. The adoption of this gun, which can be used for all purposes, will give uniformity of calibre to our batteries and its light weight will make it a practical substitute for the multitude of small pieces we now have about our ships, as well as for the main battery itself, for it can be worked wherever the slide can be accommodated. The light weight of the gun and the mechanical attachments of the carriage and slide to aid the manipulation of the piece, make it practicable to work the gun with very few men, and thus the whole question of its use at any part of the ship is simply one of space for the slide and strength of structure to support the total weight of gun and carriage.

On the subject of the construction of the gun itself I do not propose to dwell. I am speaking to an audience the majority of whom I believe are well acquainted with the general character of the construction of the Vavasseur gun, and I refer those who wish for more detailed information on the refinements of the manufacture to an article of mine, published with drawings in the July number, 1880, of the *United Service Magazine*. My object is not to present a paper on Construction. I am taking it for granted that my listeners are acquainted with the different rival systems. I am simply presenting a proposition for the adoption of a gun built on the system which I consider superior to all others. I have studied closely the history of this construction from its origin in 1860, I have compared it carefully with rival systems, and I have watched the constant approach of others to its imitation. I have recognized in the progress of the development of other guns an almost total abandonment of the principles on which they were started, while I find in the Vavasseur gun of to-day the same fundamental principles still apparent as they were years ago. I point to unmistakable proofs of the modifications of other manufacture ever approaching the Vavasseur standard, and from all this, having no object but to reach the truth, I have arrived at a fixed and determinate conclusion on the matter of construction, and I feel secure that I have grounds for the faith that is in me. In a word I am convinced, and a man speaking from conviction speaks with no uncertain voice; I approve and recommend the Vavasseur construction.

The particular gun that I recommend is the one which I consider the best fitted for general purposes in a navy constituted of such vessels as will form our Navy for many years to come, and I advise its adoption with a full appreciation of the responsibilty that I assume in advising such an extreme measure, for you will recognize that I propose to advance at once to a point which attains to the highest development of manufacture yet attained. This shows, at least, that I have the courage of my convictions. I see no benefit to be derived from attempting to advance slowly from the low position that we now occupy in artillery, the tentative efforts of other nations are all well known to us, we cannot profit more from our own experience than we can from the well known experiments of others, we are in the favored position of being able to avail of the experience of the rest of the world without incurring the expense of the investigation, and we can adopt the results that these costly trials have achieved. What we want is to recognize facts, to appreciate the necessity of coming to a conclusion, to concentrate on one system, and to act on our convictions.

In urging the adoption of the Vavasseur gun I know that I am placing my opinion in direct opposition to that which has been expressed officially by the Bureau of Ordnance, but I make the issue. The Chief of the Bureau says in his last report, "The only foreign guns which have proved satisfactory are those of Krupp. This manufacturer declines to furnish single guns for experimental purposes; this Bureau has had a standing offer to purchase a 24 cm. and a 15cm. gun for experimental purposes, but does not think it in any way desirable to obtain a further supply abroad. The guns of other manufacturers are not of sufficient excellence to warrant the purchase of even a single specimen." I call attention to the last sentence. This is a sweeping assertion, and we must remember that it comes from a high source. It cannot be pooh-poohed, and brushed aside loosely, it demands investigation. If it be correct, then my teaching is vain. But let us inquire into the truth of this, and let us see who is this Vavasseur who is passed over nameless, in this official declaration.

We first hear of Mr. Vavasseur and the London Ordnance Works in 1860, and for several years his name is associated with that of Captain Blakely for whom was made in 1861 a 64 pdr. built up steel gun which was sent to the exhibition of 1862 in London, and was the only built up steel gun exhibited; Krupp's guns at that date were solid forgings. In 1864, Mr. Vavasseur made 11 inch steel guns for

Peru. These consisted of inner tube of Krupp's steel, reinforced at the breech by a long steel jacket, over which were the trunnions and two layers of steel rings. Three of these guns weighed (each) 12 tons, 17 cwt. Six of these guns weighed (each) 14 tons, 11 cwt.

Comparing these guns with the same size guns now in the English service we have the following points of difference.

	Bore,	Length of bore,	Weight of gun.
Woolwich gun,	11 inch,	145 inches,	25 tons.
Vavasseur gun,	11 inch,	144 inches,	12 tons, 17 cwt.

For the same length of bore we had a gun of half the weight. These guns were proved at Woolwich with charges of 60 lbs. of R. L. G. powder and projectiles of 600 lbs.

In 1866, Mr. Vavasseur built for Peru some 9 inch guns and carriages. These guns compare with the present 9 inch Woolwich guns as follows;

	Bore,	Length of bore,	Weight of gun.
Woolwich gun,	9 inch,	125 inches,	12½ tons.
Vavasseur gun,	9 inch,	127 inches,	8 tons.

The guns were proved at Woolwich with charges of 43 lbs. of R. L. G. powder, and projectiles of 233 lbs.

At this time, 1866, the largest rifled gun in the English service was the 7 inch breech loading Armstrong gun of 82 cwt., firing projectiles of 114 lbs., with charges of fourteen lbs. of powder.

In 1866, Mr. Vavasseur, with Capt. Blakely, patented the plan of using copper rings, on projectiles, and you will find in the *Revue d' Artillerie* for January 1879, page 329, that Mr. Vavasseur is given credit for first employing copper rings practically on projectiles.

In 1867, Mr. Vavasseur first employed the plan of putting the breech mechanism in the jacket instead of in the tube of the gun, a subject on which I remarked in the July number of the *United Service Magazine* for 1880 to which I called your attention above.

In 1879, Mr. Vavasseur sent to China ten 7 inch guns and a number of smaller size; in 1880, he had in hand twelve 7 inch guns and some 40 pdr. B. L. guns.

In all, there have been turned out from these works a thousand built up steel Vavasseur guns, in which the principle of the original construction has never been departed from, which have all been successful guns and which have never been known to burst nor to cause disaster. These guns have been bought by Peru, Mexico, the Argentine States, China, Japan, France, Portugal, Russia, and Spain (by the

last two for experimental purposes only). Truly, I may safely demur to the assertion of the Chief of the Bureau of Ordnance when he declares authoritatively that, with the exception of those of Krupp, "the guns of other foreign manufacturers are not of sufficient excellence to warrant the purchase of even a single specimen." I may have great confidence in the opinion of the Chief of the Bureau, but I am not willing, at his dictum, to condemn that of the experts of all the nations whom I have mentioned as customers of Mr. Vavasseur. The Vavasseur gun can be bought, it is in the market like any other article of manufacture, and I recommend the purchase of samples at least; and I do not allow myself to be carried away by the idea that, because Mr. Krupp makes the most guns, his guns are necessarily the best; I believe that the Vavasseur gun is the better, and I recognize all the improvements in the late manufacture of the Krupp gun as being borrowed from the Vavasseur construction. The disposition is shown on the part of the Bureau to go so far in the way of making a purchase as to be willing to buy a gun from Mr. Krupp, but if he chooses to decline to fill the order I can see no reason why we should permit him to block the way to our purchasing from another merchant whose goods are approved by the very responsible parties that I have enumerated. No good reason can be given for excluding the Vavasseur gun from consideration in this case except want of information on the subject of the manufacture, and on the capacity of the London Ordnance Works to fill any order that may be given to it.

Now as to the objection that will be made by some to my proposition, although the objection has no weight with me for reasons which I will give, that, in order to adopt the gun that I propose, we must purchase abroad. That the gun must be made of steel, if we are to adopt a gun of the highest development, no one will deny, and we cannot supply the material from our home manufacture. These assertions are endorsed in the last report of the Chief of the Bureau of Ordnance of the Navy in which, in relation to the first, he states distinctly his "opinion that steel is the proper material for our armaments." In relation to the second assertion that the steel cannot be produced in the United States, the Chief of the Bureau reports as to his test of the capacity of the machine shops in the country, in December 1878, when only one steel manufacturer could be found who would undertake to furnish an ingot for a 6 inch gun, and it is inferred from the remarks in the official report that the ingot is not yet delivered; and we may safely conclude that it would not be satisfactory if it were delivered, for we could hard-

ly expect success to attend a first effort in such a new industry. This is a practical confirmation, if such were necessary, of our assertion that we cannot produce steel for cannon tubes. But is this a good reason why we should remain unarmed? Is the craze of protection to be carried so far that, because we can only manufacture bows and arrows, we are to avoid profiting by the manufacture of others in order to provide ourselves with means of defense? This is the acme of folly. Why should we wrap ourseleves up in our weakness and decline to buy steel for our defense? I can conceive of no satisfactory reply that can avail at any time except when we may be engaged in war; then, of course, it is desirable that we should be found able to make our own war material, but in time of peace, as now, I see no reason why we should not purchase abroad. On the contrary, I see every reason why we should take advantage of the present time to provide ourselves from abroad, as it will be the only course, by which we can force the way towards future independence in the matter when it might become necessary for us to depend on our own resources. There is no doubt that it is within the resources and the capacity of our manufacturers to supply us with the material that we require, but they will not do it, because it won't pay. So long as we are content to go along in this *laissez aller* way, showing no determination to bring about a change, we allow ourselves to remain captive in the hands of our manufacturers who force us to take what they choose to supply us with, and our efforts are limited by the character of the material which they provide; but if they recognize that a change is determined on, and if they see us throw off the weight that they put upon us by their want of enterprise, and if they see us providing ourselves from foreign manufacturers, then indeed they may be roused to effort, and they know that successful competition would naturally bring back the custom of the Government to the home manufacture, and we would achieve the independence so desirable in this matter; but it will require some such incentive as this to force our manufacturers to incur the expense and labor of developing the manufacture of the steel which is indispensable for the tubes that we will require. It is my belief in the effect of this means of incentive that makes me counsel the purchase of foreign guns and carriages at this time; and I think that this object should be sufficient to silence all protests against foreign purchase. Besides, such a course will enable us to show to our own manufacturers exactly the material and the articles that we require, and they can enter into the competition with a full understanding of what it is that they are expected to produce.

I will recapitulate in as few words as possible. My first impressions were received and my opinions formed in the "Old School." The workings of my mind favor conservatism. I cannot be a radical in the common acceptation of the term. I would not cut myself adrift from old moorings without seeing my course clear. I grew up in the Navy with the smooth bored cannon; I saw it pass through its phases until it reached its point of perfection in the Dahlgren gun. I was a firm advocate of calibre even to the discomfort produced by manipulation of heavy projectiles. I was convinced that energy must be developed, and the only available way to do this was to keep up the calibre to the highest practicable point. The system of rifling was applied to cannon, and I find that in order to sustain the indispensable requisite, energy, it is not necessary to adhere to increase of calibre, as, under the conditions of the rifled system, the other element, velocity, which was limited with the smooth bore, and which with weight goes to make up total energy, can be indefinitely extended. I find myself in a new dispensation which does not require me to desert my old faith. In recommending a total change under the new conditions I feel that I stand firm on the old platform which has ever proved to be secure.

I hold that the change in our ordnance need not be delayed in consequence of the seeming undetermined character of our ships of war; as I believe that, for years to come, the style of our ships is already determined; and the gun that I propose as worthy of our first attention is the one of which we require the greatest number. In adopting such a piece we can the more rapidly effect the change required, and the convenient size of the gun will assist to relieve us from our present embarrassment consequent upon mixed batteries. I incidently remark on the uselessness of most of the light pieces on uncovered decks in consequence of the development in machine guns. I think that the gun that I propose has not been brought to the fore in this country in consequence of lack of information on the subject of its manufacture and of its service, and I have given an outline history of both. The great difficulty that the London Ordnance Works has had to contend against in England has been the overpowering influence of the Armstrong interests, which has entirely actuated the Woolwich clique, and has constrained the English government to throw its whole weight and influence on the side of the wrought iron, muzzle-loading gun; but you all know that this error is being recognized, and that the force of public opinion is now forcing the Woolwich authorities to advance in the direction of steel and breech loading. On the continent the éclat

of the Krupp manufacture, and the personal support of the German Emperor has enabled Mr. Krupp to pass all competitors of more moderate means for expansion. Thus Mr. Vavasseur has not found customers among those nations likely to bring his guns prominently to the notice of the world, but the long list that I have given of those who have used his guns shows that they are not without admirers, and that its advantages are not unknown. I feel very sure that, if the Bureau of Ordnance could have been induced to consider the Vavasseur gun of "sufficient excellence to warrant the purchase of even a single specimen," it would have, ere this, commended itself to the intelligence of the Navy.

THE CHAIRMAN:—I am sure that every one present will join me in offering our most hearty thanks to the distinguished officer to whose paper we have just listened with gratification and interest. He speaks with authority on all connected with Ordnance for he has made it his specialty, and has written upon it with large acceptance. I am not however, prepared to accept the plan of arming our ships of war with the Vavasseur gun. Its maker is honored as a very skilful mechanician, and his works are well known to the world and have a well deserved repute. His guns have been long offered for sale, and have from time to time been purchased and tried, but I do not know that they have been largely adopted even by those who have made purchases of them.

Some were bought by Peru and were lost in the "Independencia". They certainly have not found, so far as I know, acceptance on the Continent or in England, though perhaps the extreme conservatism that has hitherto prevailed in England gave little chance for competition with the Woolwich gun.

The success of Krupp on the Continent, has at last driven the English government to doubt its favorite gun, and it is now making new cannon of increased length, breech-loading and with large chambers.

Mr. Trevelyan, the Parliamentary Secretary of the British Admiralty, has recently stated in his speech on the Naval Estimates, that the new gun of this class, weighing eighteen tons, will pierce 13½ inches of armor at 1000 yards, thus doing the work of the 38 ton guns now in use in the British fleet. Even under the great desire to compete with the Continental navies and surpass them, England has not adopted Mr. Vavasseur's plans.

Above all things, it seems to me, we need gun makers, and that we should not buy our guns abroad, but should make them ourselves. In the event of foreign war, with our enormous sea coast and defenceless bays and harbors, we need greatly the ability to manufacture guns for their protection, and no matter what it may cost, or how difficult it may be, we should create a class of skilful gun-makers ready to supply the wants of the country in its peril. Our people have shown much energy and skill in the working of steel, and although they have not been successful hitherto in making steel guns, their ingenuity should be fostered in this direction and our national strength and

resources thereby increased. Gun makers would be worth to us all they might cost.

We all agree with Commodore Simpson in his opinion as to the deplorable condition of our Navy as to guns, and sympathize cordially with him in his desire to re-arm our ships with long ranged, breech-loading cannon of the best type.

In the name of the Institute I now have the honor to offer formally its best thanks to Commodore Simpson for the pleasure and instruction he has given us.

THE USE OF STEAM IN THE MANUFACTURE OF GUNPOWDER.

In 1862 or 1863, Col. G. W. Rains introduced into the Confederate powder mills at Augusta, Georgia, a most valuable improvement by which the process of mixing was made so much more thorough that the time required for incorporation was reduced three-fourths. The sulphur and charcoal were severally pulverized and bolted; the nitre, pulverized by disturbed crystallization, was added to these, and the mass, roughly mixed, was moistened with water and introduced into horizontal cylinders of sheet copper, 30 inches long by 18 inches in diameter. These cylinders revolved slowly on a common axis consisting of a heavy brass tube 3 inches in diameter, perforated within the cylinders by a number of holes one-eighth inch diameter. High pressure steam was introduced through this tube, raising the temperature to the boiling point, while the water produced by condensation, added to that originally used to moisten the materials, reduced them to a semi-liquid slush, which was run out of the cylinders after about eight minutes' rotation. On cooling, this mud became a damp, solid cake, the nitre, which in the state of boiling hot saturated solution had entered into the minutest pores of the charcoal, now recrystallizing. The cake so produced was transferred to the incorporating mills, and, under 5-ton rollers, was in an hour brought to the condition of finished mill cake, ready to be cooled and granulated, while, without the steaming process, four hours' incorporation in the mills had previously been necessary to produce powder of the same first-class character. The capacity for work of the mills was thus practically quadrupled, the thorough saturation of the charcoal with nitre being accomplished by the steaming, while it remained for the rollers merely to complete the mixture of the whole mass and give the required density to the mill-cake.

Am. Chem. Jour., Vol. 2, No. 6, p. 423.

PROFESSIONAL NOTES.

These articles have not been read before the Institute but are inserted by order of the Executive Committee.

DEFLECTING ARMOR.*

To obtain the best results deflecting armor should have a hard, smooth surface, and possess sufficient rigidity to turn the ends of shot and bring them sidewise against it; the great penetration obtained by elongated shot is due to the concentration of energy on the small area of their cross section. The area of a longitudinal section of a shot of three calibres' length is almost four times as great as the area of the cross section, consequently the penetration of such shot would be proportionally reduced if they were made to strike on their sides. If the armor does not possess a hard surface, the local give will permit the ends of the shot to bite and the armor will be penetrated. Armor of a proper thickness, having a hard, smooth surface, disposed at an acute angle, will possess considerable elasticity when struck by shot, by yielding bodily to it. Even if the entire energy of shot is absorbed by armor, if the shot is made to strike upon its side, it could be resisted with a moderate thickness of armor.

The greater the difference between the length and the calibre of shot —other things being equal—the more easily the shot can be turned, for there will be less weight in the end. It may be assumed that the entire weight of the shot is resident in its centre of gravity, and as the leverage is greater in a long shot, it would be more easily turned than a short one of equal weight. Great penetration is obtainable only with shot of great length in proportion to their diameter, but increased length implies increased area of longitudinal section, consequently if the end of the shot is turned by deflecting armor, the advantage of increased length is completely neutralized by increased surface of impact.

Owing to the perishable nature of wood, when used as backing for armor, it is desirable to avoid its use, but wood can be applied with as

*See article on Deflecting Armor in No. 15, Vol. VII, Proceedings of the Naval Institute.

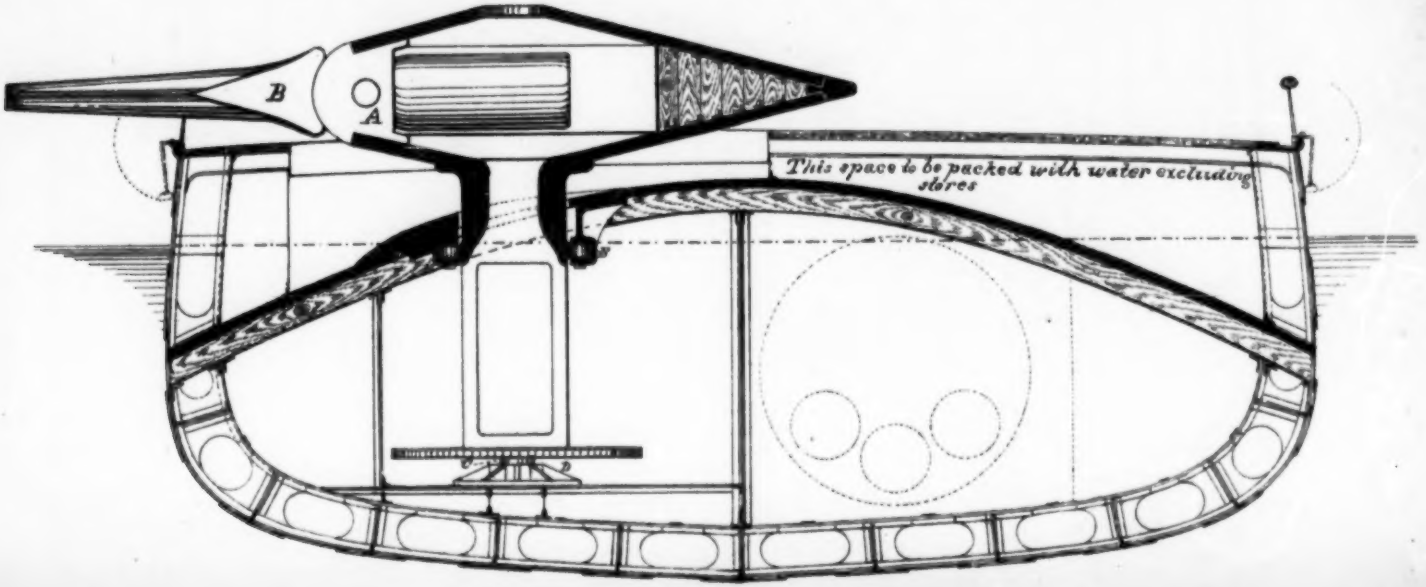
great advantage as backing to deflecting armor as to the vertical type. The Interior Shield, or turtle back, composed of compound armor, having a hard, smooth surface, could be supported on beams of wood eight or ten inches thick, bent to the curved form, bolted together, and secured to the vessel's sides.* If found desirable the Deflecting Turrets could be filled up solid with wood, except the space in the centre between the guns, where the men stand to operate them; with the hydraulic appliances for loading the guns very little space inside the turrets is necessary, two men to manipulate the hydraulic gear of each gun being all that would be required, together with an officer to direct them. The latter could operate the valves regulating the hydraulic power by which the turret is rotated, and by means of observation slits he could keep the guns constantly trained on the enemy, and the operations of loading and firing could go on uninterruptedly, as the loading apparatus would revolve with the turret. There is ample room in the double convex turrets for an officer and four men, and in event of casualty a relief force could be promptly sent into the turret from beneath the Interior Shield.

The great length now given to guns renders the adoption of the breech loading system necessary, as it would be almost impossible to load guns of such inordinate length from the muzzle; it is also impossible to protect guns of such great length with armor, and to keep the weight within practicable limits. Guns are now made as much as thirty calibres in length, this proportion if applied to the 100-ton Armstrong gun which has a bore of 17.72 inches would give a length of 44ft. 3in. These long guns give the best results, but as it is impossible to make turrets of sufficient size to protect them, their most vulnerable parts, the muzzle ends, would be entirely exposed, if they were used on ship board. It is therefore proposed to make the guns in a deflecting form, by which a very fair measure of protection can be obtained with a minimum of weight. Fig. 1 represents a plan view of a double convex turret with two guns mounted in it. Fig. 2 represents a cross sectional elevation of the same turret on the line *a b* showing the cross section of vessel and turret, with a gun in elevation.

The guns in this turret are mounted on trunnions and oscillate for elevation and depression on heavy trunnion blocks A, which are firmly secured to the armor casing of the deflecting turret, the guns therefore

* The wood backing under the Interior Shield, as well as that filled in the deflecting turrets, could be taken out if it became decayed, and renewed without impairing the integrity of the vessel.

Fig. 2



have no recoil and the thrust of the discharge is received on the trunnions and on the joint J, fig. 1, made by the junction of the gun with the trunnion block A; this joint is an arc described from the trunnion centre. Fig. 3 shows a cross section of one of the guns near the muzzle. The deflecting form given to the guns would make it difficult to seriously injure them by side shots. The guns are set back in the armor of the deflecting turret so as to brace them against side shots. At this point the side of the gun presents a flat surface B, fig. 2, to a similar surface of the turret armor. Fig. 4 represents a cross section of a gun on the line *e f* showing the flat surface presented by the side of the gun to the turret armor, by which it is braced against side shots.

Recoil for naval guns was of great advantage with muzzle loaders, as by it the guns were run in to reload, but with breech loading guns there is no good reason why it should not be entirely done away with; unless it is retained for the purpose of automatically opening the breech to reload, which would be hardly warranted by the advantage gained. Guns will throw shot with somewhat greater force if they are not permitted to recoil, but the great advantage in doing away with the recoil would be the much greater simplicity, and by having the guns firmly secured to the armor, there would be no danger of their getting loose in a sea way, and they could therefore be used under circumstances that would preclude their use if they were mounted in the ordinary manner so as to admit of recoil. With guns firmly secured to the turret armor the shock of the discharge would be communicated to the entire turret, and as the turret rests on a central spindle C, fig. 2, stepped in a hydraulic press D, supported by the keelsons of the vessel, and is firmly supported laterally by the Interior Shield, or turtle back, the shock would be distributed over the entire vessel, and if the guns were discharged abeam, it would probably roll the vessel a few degrees in line of recoil. In an ordinary vessel it would not be expedient to mount heavy guns without providing for recoil, as the ship would most likely receive serious damage from the shock of their discharge, but a vessel fitted with an Interior Shield is braced in such a manner as to endure such shocks without receiving injury. Mortars are mounted without providing for recoil, and, when on shipboard, their platforms are laid up solid from the vessel's bottom. The lateral support afforded by an interior shield will give ample bracing to admit of the mounting of heavy guns without recoil.

While the double convex turrets with deflecting guns would seem to be best adapted to the heavier class of vessels, to be used for coast de-

fense, and to operate against forts and land batteries, the V shaped turrets would seem to be best adapted to cruising vessels.

Fig. 5 represents a deck plan of a vessel with two V turrets. These are intended to deflect shot laterally and admit of mounting the largest size gun; one gun being mounted on each turret en-barbette. The turrets are erected on circular platforms, in circular hatches through the Interior Shield, which supports them laterally by means of anti-friction rollers, protected beneath its edge. The turrets are to be supported on central spindles, stepped in hydraulic presses resting on the keelsons of the vessel, and are to be rotated by hydraulic power, the valves regulating which are to be under the immediate control of the officer in command of the gun, who can keep his turret trained so as to receive all shot at a deflecting angle. So long as shot come from only one direction, and the gun is kept trained in that direction, this form of turret will be practically invulnerable; for it admits of a thickness of armor that will be found impenetrable at an acute angle.

By the aid of hydraulic power these turrets can be rotated with great celerity and precision and held firmly in any desired position by the officer in command of the gun, and so long as he has but one adversary to contend with, and he keeps his gun trained against him, his armor cannot be penetrated.

It is within the bounds of possibility to build a vessel of very moderate size on this plan, fitted with an Interior Shield for the defence of the water line, the crown of which would rise amidship about a foot above it, and would present a practically constant angle of impingement to horizontal shot at the water line, as the vessel rolled; with two V turrets having on each a large rifle of great length. Such a vessel having superior speed, which would enable her to choose her own position in combat, say from 300 to 500 yards distance from her adversary, would be more than a match for any vessel clad with vertical armor now afloat. She could drive her shot through the vertical armor of her adversary, who in return, at that distance, could not strike her at a penetrating angle. So long as her opponent could not chase down, and fire plunging shot into her from guns depressed, it would be an unequal combat with great odds in favor of the vessel armored on the deflecting system; but even if her adversary possessed the speed necessary to force her to fight at very close quarters, where they would exchange plunging shot, if the vessels were of equal size and armament, the ship armored on the vertical system would possess no advantage.

A vessel armed with two large guns mounted on V turrets, one on

Fig. 5

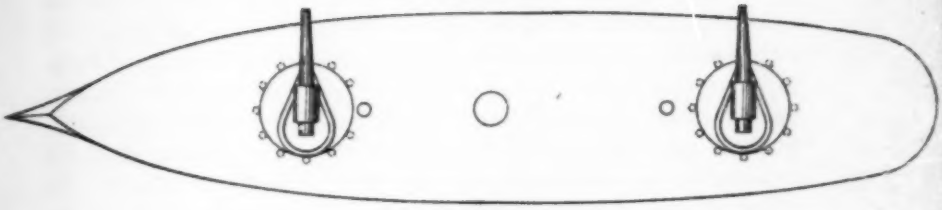


Fig. 4

Fig. 1

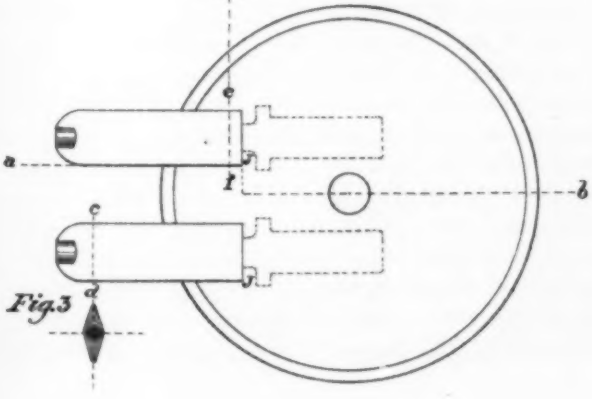


Fig. 3

each end, would have the advantage of an all round fire; and would be able to train both guns sharp on the bow, or over the stern. A vessel having but two large guns, it would seem to be a better arrangement to have them mounted separately. than to have both guns in one circular turret where a single shell striking the turret near right angles, might kill or disable the crews of both guns and lead to the loss of the vessel.

Vertical armor protects by deflection only, whenever it is struck at near right angles to its surface it can be penetrated, and the only protection to be obtained is to so dispose the armor that it cannot be struck except at a deflecting angle, thereby presenting the much greater area of the longitudinal section of the shot to the armor, and throwing it off. Shots are apt to be deflected downward as well as upward, and a flat armored deck situated at or near the water line, which would be liable to receive shot under it as the ship rolled, and which would be inclined so as to deflect them downward through the magazine and boilers, would be a positive source of danger to a vessel fitted with it.

N. B. CLARK,
P. A. ENGINEER, U. S. N.

THE BOMB THAT KILLED THE CZAR.

Since the assassination of the Czar we have looked with interest for a description of the weapon used by the assassin as it was rumored it was of novel construction and of great power. All attempted descriptions that we have met have been meagre and imperfect, the most detailed, and that claiming the greatest accuracy, being found in *Le Gaulois* of March 29th. From this we gather that the bomb consisted of a sheet iron cylindrical box 15 cm. high and 10 cm. in diameter. On the left hand side was a copper tube 9 mm. in diameter and extending the whole length of the box from top to bottom. This enclosed a hermetically sealed glass tube of equal length and 3 mm. in diameter, which was filled with sulphuric acid. The space about the glass tube within the copper tube was filled with a mixture of Berthollet's salt and a salt of antimony. At the longitudinal centre of this copper tube its diameter was increased to 3.1 mm. for a distance of 1.9 mm., in order to admit of a disc of lead of slightly smaller dimensions which was perforated and free to slide a small distance on the glass tube. This lead disc was intended to break the tube by its impact when the bomb was arrested in its flight and thus liberate the sulphuric acid. From the side

of this enlargement in the copper tube another tube 4 mm. in diameter filled with pyroxyline led across the box to a copper tube 1.6 mm. in diameter and 35 mm. high, filled with gun cotton, placed in the lower right hand corner of the box. All of the rest of the space in the box was filled with nitro-glycerine. This is a very crude description and undoubtedly in some respects incorrect, but it may, in the main, fairly represent the construction. As Berthollet's salt, an ammoniacal salt of silver, is so sensitive as to be readily exploded by the least touch, it is improbable that it should have been used, and if used the salt of antimony and sulphuric acid would have been unnecessary, but it is probable that a mixture similar to that used in the Harvey torpedoes was employed. The distinction between pyroxyline and gun cotton is also vague. C. E. M.

REVIEWS.

No publication will be noticed under this head, unless a copy to be deposited in the library of the Institute is sent to the Corresponding Secretary, at Annapolis, Md. All reviews must be signed by the writer.

THE NORDENFELT MACHINE GUNS (PALMCRANTZ'S SYSTEM). JOURNAL OF THE ROYAL UNITED SERVICE INSTITUTION, NO. CVIII.

In these days of many men of many arms, when—as a rule—no inventor thinks any other arm is in any way to be compared with his own, it is quite remarkable to find any machine gun authorities agreeing in a comparison, even in a general sort of way.

In a pamphlet on the Gatling gun, published in 1874, it is stated that "The same class of men who doubted that the railway would ever take the place of the stage coach, ...; the spinning jenny of the time honored spinning wheel, ..., may dogmatically decide in the negative" anent the necessity of using machine guns; and last June (1880), Mr. Nordenfelt in a paper read before the Royal United Service Institution stated that "Machine guns are to the art of war what Arkwright's spinning jenny was to weaving". When we come to inquire which one of the machine guns most nearly answers to this description, we are met by so many very different and equally emphatic assertions, both as to points of comparison and as to what constitutes excellence, that we are in self defence forced to accept the dicta of some one authority, or form our opinions in accordance with procurable evidence. This last is found to be almost impossible because the best evidences, official reports of both service and proving ground tests and trials, seem to vary with an, as yet, undetermined function of the longitude of the place of such tests and trials. If, however, we accept Mr. Nordenfelt as such an authority, it would appear from his paper that the Palmcrantz system of machine guns is better adapted to fulfil the requirements than either the Gatling or the Gardener. But in regard to this it may be well to consider some of the points presented.

We learn that the "supposed difficulty of supplying ammunition for a machine gun in the field is not great—always granting that the gun uses the same ammunition as the rifle; because. . . . ., the total ammunition fired from the machine gun would probably not exceed what would have to be fired by the corresponding number of rifles before the same object were gained".

Evidently the "corresponding number of rifles" does not mean the number corresponding to that of the barrels of the machine gun; for, if a Nordenfelt five barrelled gun could not, under favorable circumstances, gain a greater object than five riflemen, there would be no earthly excuse for its existence; the meaning would seem to be that the amount of ammunition used, by a machine gun on the Palmcrantz system, to gain a certain object would probably equal that used by rifles to attain the same object, and could be just as readily supplied; so that if the machine gun fired—as it should to be efficient—as fast as one hundred riflemen, who march loaded down with cartridges, it could be readily supplied by one hundred men carrying ammunition; but it is difficult to understand just where these hundred men are to come from when we are told that "six or eight men" constitute a gun's crew; nor is it plain how ammunition, ready for firing, can be more easily transported in the bulky and heavy Nordenfelt magazines than in the light, compact, cartridge-factory pasteboard packages for use with the Gardener and with the Gatling when the *feeder* is employed.

"I hope", says Mr. Nordenfelt, "that Dr. Gatling will excuse my saying that his revolving gun with movable breech supports, is tied down to the first part of my second basis of division, viz., that his gun can only fire rifle [musket calibre] ammunition with advantage". The application of this remark is not quite clear in face of the fact that for more than a decade Gatlings of 1″ calibre have been in use, in many parts of the world, have fired their projectiles with more or less "advantage", and have never, it is believed, killed any one standing in rear of them. Nor is it easy to understand why the breech supports of the Gatling are more movable than those of the Nordenfelt; for if by "breech supports" the action block and breech pins are meant, they must be movable as are the Gatling locks, in order to allow the chambers to be loaded. Mr. Nordenfelt himself says "when the block [the action block] is moved forward, these [the breech pins] push forward the cartridges etc,"—just as do the Gatling locks; but, at the moment of firing, the Gatling system receives the shocks of the successive explosions upon the solid recoil piece fixed upon the immovable cam,

while the Palmcrantz takes up the recoil of a whole volley upon the action block which "is moved forwards and backwards by the action of the firing handle."

It is curious to note that Mr. Nordenfelt's remark, "The Hotchkiss gun is a development of the Gatling idea," is almost an exact expression of Dr. Gatling's opinion, were we to substitute *Nordenfelt* for "Hotchkiss" and *an arrested* for the indefinite article; and indeed, if one compares the plan of the Palmcrantz system with that of the Gatling, developed upon a plane, as shown in a Gatling Gun publication of 1874—the date of the appearance of the Palmcrantz system—it is not very difficult to understand upon what the Doctor bases his impression, an impression it may be mentioned in passing, quite different from that of an American naval officer, who, being asked upon the appearance of the Palmcrantz what it was like, said, "Why, it's just the old Requa battery, that Gilmore used at Charleston, a dozen years ago, with a slightly improved feed."

When Mr. Nordenfelt said "I would, however, hardly class the Gardener gun with machine guns, because the single barrelled gun Mr. Gardener himself especially recommends is rather a clever repeating rifle, while it at the same time requires the full service of men and equipment of a machine gun," he was probably not aware that at the time he spoke, the Gardener system was being applied to four and five barrelled guns, or that the system was particularly applicable to two barrelled weapons, which, with less than half the number of barrels and with a corresponding decrease in weight have equalled what Mr. Nordenfelt calls the "tremendous rapidity" of fire of his light five barrelled gun, viz., five hundred rounds per minute. He was, however, quite correct in stating that this "clever [double barrelled] repeating rifle" would require the full service of men and equipment of a machine gun; but it is not clear why this should be considered an objection to the arm as compared with the Nordenfelt, since "the full service of men and equipment" can with equal ease transport ready for firing at least twice as much ammunition in the Gardener packages as in the Nordenfelt magazines.

We notice in regard to the working of the Palmcrantz that "one single gunner can fire without any assistance, with his right hand rapidly, an entire hopper full of cartridges, while his left hand is free to attend to the elevating and traversing gear," and that "with the comparatively slow movement of the mechanism no jams nor hitches are likely to be caused by the mechanism." The first of these considera-

tions would seem to be of questionable desirability, since the average man has sufficient occupation in either pointing or firing; and since, unless the mount be very awkward, the man who fires cannot get his eye down to the line of the sights while in position to exert his full power on the firing lever or crank—but both points are common to all machine guns of any prominence.

By the "regulator" for the Gatling, Mr. Nordenfelt evidently means the adjusting nut; but that the use of it "requires great judgment on the part of the gunner" is not, in the light of experience in our Service so evident. The writer once assisted in firing sixty four thousand cartridges, in a single day, from an old model Gatling—which was not regulated or wiped out during the trial—but failed to note that the regulator gave trouble: with the rear adjusting nut that has been in use some years, it is hard to conceive what the "trouble" Mr. Nordenfelt speaks of could possibly be.

We can understand Mr. Nordenfelt's arguments in favor of the use of mitrailleuses—by which term he designates musket calibre machine guns in general—because we have been accustomed to hear them from machine gun admirers for the last fifteen years; but when he illustrates the superiority of his particular gun, the light five barrelled Nordenfelt, by saying that it fires "about five hundred rounds per minute, or, for spurts of one hundred shots at a time, at the rate of nearly eight hundred shots per minute", we are again hopelessly adrift as to the point of supremacy; for the two barrelled Gardener, as made in the United States, is fired with equal rapidity, while the light navy Gatling fires fully one thousand rounds per minute, or, for spurts of forty shots at a time at the rate of fully twenty four hundred shots per minute.

The following table shows the comparative weights and rapidities of five of the Nordenfelt and Gatling systems according to figures furnished by Mr. Nordenfelt, and from United States official sources.

10 Barrelled Guns.

System.	Weight.	Rapidity.
Nordenfelt.	280 pounds.	110 rounds in 5 sec.
Gatling (U. S. Army).	198 pounds.	40 rounds in 1.25 sec.

5 Barrelled Guns.

System.	Weight.	Rapidity.
Nordenfelt.	110 to 135 pounds.	70 rounds in 5. seconds.
Gatling (U. S. Army.)	100 pounds.	40 rounds in 1.75 sec.

The short ten barrelled navy Gatling fires more rapidly than either of the army guns above mentioned; the model was determined upon as that which would give the best results for general use aloft, on deck, or ashore, and is apparently fitted for all the kinds of work that Mr. Nordenfelt assigns to both his light five barrelled and heavy ten barrelled musket calibre guns for naval uses.

Mr. Nordenfelt assumes that 1″ solid shot are the proper projectiles for anti-torpedo boat guns in opposition to the generally received opinion which seems to favor 1.″5 calibre shells; but we can readily follow his reasoning upon the point in question, and when he says, after clearly giving the probable conditions under which the guns would be needed, "it is the volley, with the slight spreading caused by the vibration of the weapon, which gives me the best chance of hitting," it is clear that he is right—provided that we are considering the chance of a single shot to a volley. But if we are considering the chances of making a hit in a given time during which a certain number of rounds can be fired, and at all instants of which the chances are equal that adverse circumstances shall render futile any single attempt, the volley fire does not seem to have all the advantages over the continuous; and, indeed, it would even seem that the supremacy of the four barrelled 1″ calibre, solid projectile throwing Nordenfelt gun could be granted only on the hypothesis that among the varying conditions of practice at sea, which Mr. Nordenfelt so clearly describes, the Palmcrantz system shall always be fired at the right instant, while the revolving system gun shall be fired at the wrong time, three times out of four. This as regards the 1″ calibre solid projectile guns; but if we compare the chances of hitting when the revolving system gun throws 1.″5 calibre shells, even if we limit the number of shell fragments to four, the superiority of the volley fire would seem to disappear when considering only a single instant and single attempt; and therefore we can easily understand how in the United States, in France, in Germany, in Denmark, and in many other countries, there might be held the theory that the 1.″5 Hotchkiss was a better anti-torpedo boat gun than the 1″ Nordenfelt; a theory that is proved to be all wrong by the reports of official trials off Portsmouth last year, published by Mr. Nordenfelt, and all right by the reports of official trials in the Helder the year before, published by Mr. Hotchkiss. The following extracts from these reports will illustrate the general way in which longitude, as stated above, affects the action of machine guns.

Results of firing against Torpedo-boat Models at Sea during a Single Run. Guns in both cases mounted side by side and worked for the same time and under exactly identical circumstances.

Gun.	When.	Where.	Shots.	Hits.
Nordenfelt.	1880.	Off Portsmouth.	118.	62.
Hotchkiss.	"	" "	52.	11.
Hotchkiss.	1879.	The Helder.	132.	54.
Nordenfelt.	"	" "	85.	12.

If by repeated trials Mr. Nordenfelt proves that 1″ calibre solid shot are the proper projectiles for anti-torpedo boat guns, the Gatling Gun Co. will probably begin to manufacture its 4 barrelled 1″ calibre solid steel projectile gun of three and a half hundred weight, designed some half dozen years age but never manufactured because the demand for guns using such projectiles did not warrant the expense of change of model and plant.

The lack of detail in Mr. Nordenfelt's mention of his 1.5″ calibre single barrelled gun makes it difficult for one not familiar with its merits to understand in what way it is superior to the service 1.45″ Hotchkiss or the single barrelled Gatling of that calibre.

Having followed Mr. Nordenfelt thus far, it may be well to notice the points of superiority claimed for other systems of machine guns. Admirers of the Gatling system claim that for musket calibre guns, it is superior to the Palmcrantz in that it furnishes greater rapidity of fire; is lighter; less awkward in shape for work in tops, boats, and other confined spaces; protects its mechanism better; is more enduring; furnishes continuity of fire at such a rate that all the good effects of a volley may be attained without undue recoil; allows the piece to be kept constantly bearing on the object while the fire is constant for an appreciable time, even in spurts; uses ammunition from a neat feed case, easily handled aloft and in confined spaces, or from cartridge factory packages.

The supporters of the American Gardener system claim that it is superior to the Palmcrantz in furnishing double the rapidity of fire per barrel; in giving a continuous fire; in being neater, lighter, and better protected in its mechanism; in being more enduring, since it is not strained by volleys; and in not requiring its ammunition to be stowed in magazines, in order to have it ready for firing.

The service Hotchkiss among other claims for superiority over the

1" calibre Palmcrantz has the following: continuity of fire; greater ease of pointing, and consequent greater chance of hitting, other things being equal; capability of being kept bearing on a swiftly moving object and not being thrown off by volley firing; greater safety to gun's crew, and more practical mount; while in general, in the words of a Danish officer who reported on a competitive trial to the Minister of Marine, "The Palmcrantz gun was proved by the trials to be in action far inferior to the Hotchkiss revolving cannon."

But if Mr. Nordenfelt was so confident of the supremacy of the Palmcrantz system last June, how much more so must he be now, since it has so cleverly won nearly all the laurels of last winter's trials at Shoeburyness; trials which really ought to teach something as they were made without the use of the wrapped metal cartridge. Under the circumstances it is natural that he should exclaim, "I cannot speak too highly of the trials in England"; while it is perhaps not unnatural that Dr. Gatling with his gun, possibly feeling the malign influence of the longitude, should remark, "From information I have obtained, I judge that the late trials of the machine guns at Shoeburyness were poorly conducted and that great injustice was done the Gatling gun."

The official reports of these trials must be very favorable to Mr. Nordenfelt's guns, but whatever they are to be, it seems that they will not decide the adoption of any particular system in England, for already a new machine gun committee has been appointed to institute renewed trials.

From what little information the writer has been able to gather, it would seem to him that the Nordenfelt guns are very excellent weapons and that they are growing in excellence; as, for example, in the matter of the locking of the trigger comb, which will, it is thought, tend to prevent a repetition of the embarrassing and disagreeable occurrences, which took place on board H. M. Ships "Comus" and "Northampton." It does not appear, however, that they are in any respects superior to the machine guns adopted for use in our Navy.

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AMERICAN ACADEMY OF ARTS AND SCIENCES. PROCEEDINGS, VOL. XVI, PART 2. The bolometer. Prof. S. P. Langley formerly of the Naval Academy has invented a very ingenious and delicate instrument which he calls the bolometer oractinic balance. The determination of the relative amount of energy, in the form of heat, light and actinic rays, in the different parts of the spectrum has engaged the attention of physicists during some years. All measurements heretofore have been made by passing the beam through a prism and then by exposing a thermopile to the action of successive portions of the spectrum throughout its entire length. It has been found however that the prism exerts a selective action upon the rays which pass through it, depending upon the nature of the material from which it is made, and also by contracting the red and ultra red ends it gives false value to the measurements made upon them. It was proposed some time since to substitute a diffraction grating for the prism but the rays reflected from these were so feeble that the thermopile was found to be far too coarse an instrument to be sensitive to them. With the bolometer it has been possible however not only to detect their presence but to measure their intensity.

The instrument is constructed of two or more thin strips of metal arranged on the principle of the Wheatstone bridge. The strips are so arranged as to be under exactly the same conditions of temperature, etc., as regards surrounding objects, while it is possible to allow the rays of the spectrum to fall on one strip and shield the other. According to the law discovered by Siemens when the rays fall on the metal strip it becomes heated and its resistance to the passage of an electric current increases with the temperature. If now both strips are connected with a delicate galvanometer and a current passed through them before the experiment is made produces equilibrium, when one is exposed to the action of the rays, the resistance in it is increased and the needle is deflected. The amount of deflection measures the temperature of the strip. With this instrument a difference of $\frac{1}{10000}$ of a degree Centigrade produces a measurable deflection and a change of $\frac{1}{100,000}$ of a degree can be noted. The strips of metal usedare from $\frac{1}{2000}$ to $\frac{1}{12500}$ of an inch thick.

With this instrument Prof. Langley finds "that (contrary to the statements of our text books, and contrary, as I think, to most present scientific opinion) the great proportion of all solar heat received at the earth's surface does *not* apparently lie in the non-luminous part of the spectrum. Not only is the heat maximum in the luminous part, but the total sum of non-luminous heat (as far at least as our measures extend) is relatively small, the joint effects of the ultra red and ultra violet radiations, (so far as measured) not making up the sum of those in the visible portion. This is a result to me unexpected, but which I think may be relied on."

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MITTHEILUNGEN UBER GEGENSTANDE DES ARTILLERIE UND GENIE-WESENS. 1880, PART 5. The influence of the ground upon infantry fire. The cold punching of iron. Experiments with a 6.5 cm. sectional mountain howitzer.* Breaking up of two cast iron guns with dynamite.* The composition of several specimens of gun cotton by Capt. Philipp Hess.

According to recent reports the gun cotton produced by the Lenk-Abel process is in some measure unreliable. The attention which has recently been given in Austria to the utilization of its important properties as an explosive for war purposes has been extended also to the investigation of its differences of composition and has proved the existence of a great number of gun cottons. Several analyses have been made, the results of which are embodied in the table at the end of the paper together with data from other sources.

The processes employed in the analyses may be briefly described as follows. As it is essential that all calculations should be made upon the dry substance this is the first step in the process. The finely powdered cotton is enclosed in a glass tube through which a current of dry air at a temperature of 40°C is sent, until the weight is constant. Should it be desired to estimate the hygroscopic moisture it is simply necessary to weigh the tube and contents before drying. With compressed gun cotton the pulverization is essential as the hygroscopic condition will not be the same throughout the whole cartridge.

The ash is determined by the method given in this Mittheilungen (1879, N. S. 124) which consists in heating the dried gun cotton (about 5 grams) in a platinum evaporating dish with pure melted paraffine until the combustion is complete.

The soluble substances are obtained as an aqueous extract by digesting a weighed quantity of the cotton with water, and consist of alkaline carbonates. These may be better determined from the treatment of the ash with chlorhydric acid. The alkalies are dissolved and the remaining insoluble matter may all be estimated, without sensible error, as sand.

Another portion of about 5 grams of the dried and pulverized cotton is placed in a glass flask saturated with absolute alcohol and then ether is poured over the mass. After shaking thoroughly the flask is closed and left to digest at the ordinary temperature until the undissolved threads have gathered in flocks. The clear liquid is now filtered through a weighed linen filter and washed with the ether-alcohol mixture. The filter and residue are dried in a current of air at 40°C and weighed. The difference between the weight of the original cotton taken and of the residue gives the amount of mono and di-nitro cellulose. The residue contains the tri-nitro cellulose and unnitrified cotton, together with the portion of the ash which is insoluble in water.

* See No. 15, Proceedings Naval Institute.

To separate the trinitro cellulose from the unnitrified cotton an aliquot part of the residue from the previous operation is heated in a glass flask with an excess of a concentrated solution of sodic sulphide. The trinito cellulose is thus brought into solution while the unnitrified cotton is not acted upon. It is then filtered through a weighed linen filter, washed with distilled water until a drop no longer imparts a color to acetate of lead paper, then with dilute chlorhydric acid to remove a trace of sulphide of iron and finally with distilled water. The filter is then dried in air at 40° C. and weighed. The residue contains the unnitrified gun cotton together with the mineral matter insoluble in chlorhydric acid.

In the following table *a* and *b* are gun cottons from the Kruppamühle factory in Oberschlesien. Specimens *c* and *d* are from another continental factory. Specimen *e* is from Waltham Abbey, made in 1874. Specimen *f* is the substance known as tonite made at Faversham. Analyses *g* and *h* are by Muspratt with Abel's gun-cotton. Analysis *i* is by Champion and Pellet and is calculated on gun-cotton free from ash.

Designation of Specimen.	Composition of Several Specimens of Gun-cotton, Made by the Lenk-Abel Process. Percentage in specimen of								
	Trinitro cellulose.	Mono and Di-nitro cellulose.	Cellulose.	Aqueous extract.	Sand.	Other substances in Ash.	Total.	Analyst.	Remarks.
a	88.60	5.51	3.30	1.64	0.37	0.17	99.59	Capt. Hess.	
b	89.10	5.37	3.28	1.40	0.33	0.69	100.37	Lt. Dolliak.	
c	80.33	9.44	8.40	0.25	0.06	1.56	100.04	Capt. Hess.	
d	80.57	9.20	8.41	0.26	0.05	1.60	100.09	Capt. Hess.	
e	85.53	6.45	3.57	2.43	0.22	1.86	100.06	Lieut. Dolliak.	
f	93.13	5.63	1.05	—	0.19		100.00	Capts. Hess and Schwab.	The aqueous extract contained only tonite.
g	81.50	12.00	5.00		0.5		99.50	Muspratt.	
h	82.50	12.00	4.00		0.5		99.50	Muspratt.	
i	93.00	6.00	1.00	—	—	—	100.00	Champion and Pellet.	

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MARCH. Marine Steam engines. General table of contemporary naval history (1862–70.) Captain Chabaud-Arnault devotes this portion of his work to the history of the naval operations during the late war in the Uuited States. He mentions concisely the principal engagements, for the purpose, as he says, of showing the undeniable influence they had upon the result, and also the principal occasions when torpedoes were used; and in conclusion he makes the following remarks which we translate. "Thus, as we have already said, the blockade of the Southern ports, the conquest of the Mississippi, the transport of troops and the aid given them upon the enemy's soil;—these were the three great aims of the federal navy during the war of secession. Without the blockade it is probable that the Washington cabinet would have been forced to recognise the independence of the South; the failure of the federal squadrons on the Mississippi would have prolonged the war several years; the want of transports would have prevented the Navy making those fortunate diversions which facilitated the blockade of the Southern coasts and at the same time lightened the task of the armies of the Potomac and Mississippi; and, finally, without the aid of the naval artillery, the fate of those very armies or of their detached corps would have been exceedingly doubtful in more than one battle, and in many of the expeditions. If we take into consideration that in order to bring about the great result we have just tioned the Union fleet had to snatch victory as well when fighting vessel against vessel as at Memphis, as when fighting against squadrons protected by formidable batteries as at New Orleans and Mobile; that it had to reduce alone or with the aid of land forces, a multitude of strong

places and of less important works; to engage in battle almost always successfully, with the southern iron-clads along the sea-coast and in hostile rivers; and finally to chase the confederate cruisers on all the seas of the globe: if we think, then, of so many operations, so complex and of such a varied nature accomplished by this fleet, we shall get an idea of the immense part it had to fill during the war of secession.

At the end of this work, we will show the influence such a struggle had upon the progress of Naval art. At present, let us be contented to render justice to the seamen who brought it to such a happy end. From the beginning of the war, we see them carry under the fire of the confederate forts, without hesitation, their old steamers and fragile gunboats of wood, or protected with inadequate armor. But it is to Admiral Farragut especially that honor redounds for showing, by more than one aid to the Union cause, what could be done with such a fleet hitherto regarded as useless. At New Orleans, Vicksburg, Port Hudson, and even at Mobile he did not fear with wooden corvettes and gun boats to brave a series of works behind which the Confederates believed themselves secure to defy the attacks of a formidable fleet. It is necessary to study in detail the engagements fought by this illustrious seaman to appreciate the great qualities of which by many circumstances he proved himself possessed: —his precaution before battle, his skilful foresight in manœuvre and remarkable energy in action! With him, how many other remarkable officers could we name: Admirals Porter, Davis, Foote, Goldsborough, Captain Worden, who commanded the Monitor at Hampton roads, Lieutenants Flusser and Roe,—who, the first dared to fight by ramming the iron-clad Albemarle with wooden vessels simply—Cushing, who destroyed this same vessel by means of a torpedo—many others still, as skilful as brave. The confederate navy too can cite with pride some names, for we should not forget under what unfavorable conditions its brave officers were obliged to fight. The hulls of the confederate vessels, rams or gun boats, were crudely constructed, with inadequate armor, with machinery continually subjected to damages, and with guns relatively less powerful. Yet with *matériel* less defective what might not have been expected of officers like Rear-Admiral Buchanan, who commanded successively the Virginia at Hampton Roads and the Tennessee at Mobile,—like the courageous Captain Montgomery, commanding the squadron destroyed at Memphis,—like the heroic Lieutenant Dixon, whose triumph in sinking the Housatonic was his shroud! In fine if the federal sailors had the honor of being the first to use turret vessels, it was their adversaries who inaugurated with the Manassas and the Virginia the ram, and who, guided by the counsel of the illustrious Maury, showed the power of torpedoes as offensive and defensive weapons. The destruction of the Housatonic preceded that of the Albemarle and about twenty federal vessels were sunk during the war by the stationary torpedoes of the Confederates."

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